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SELF INSTRUCTION IN NAVIGATION

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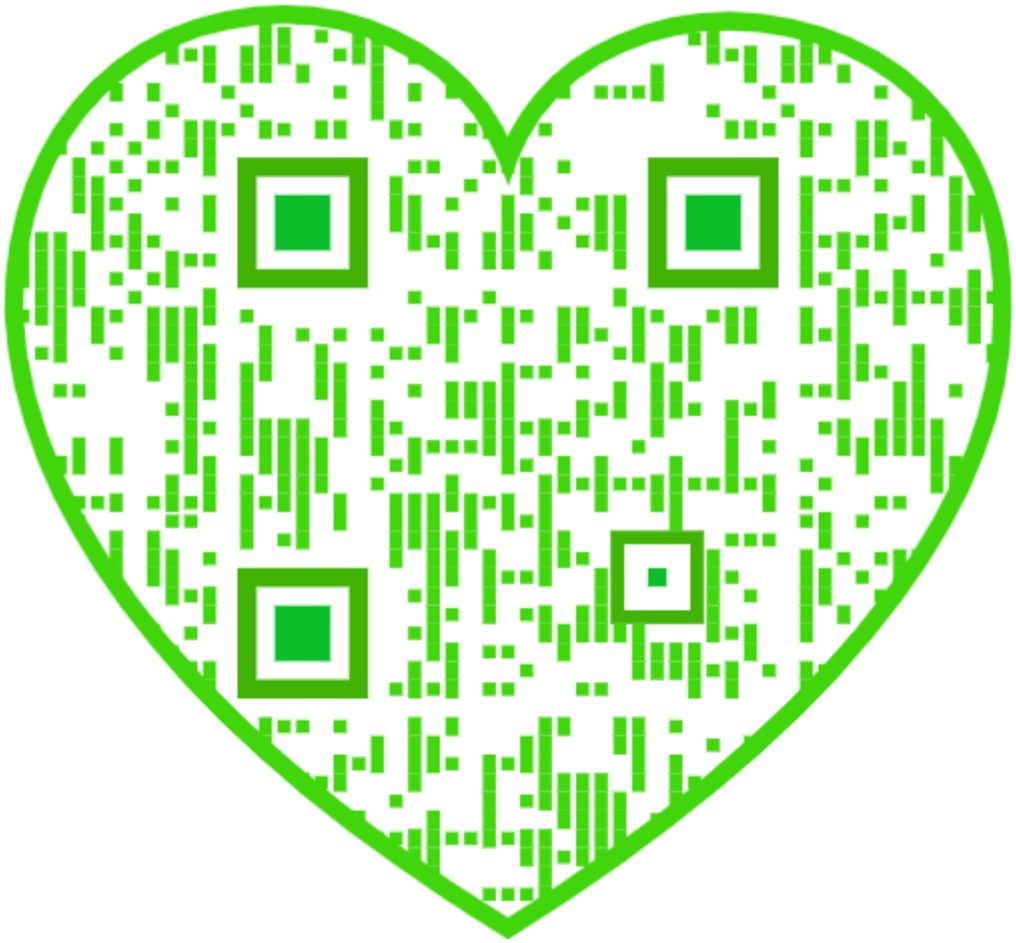

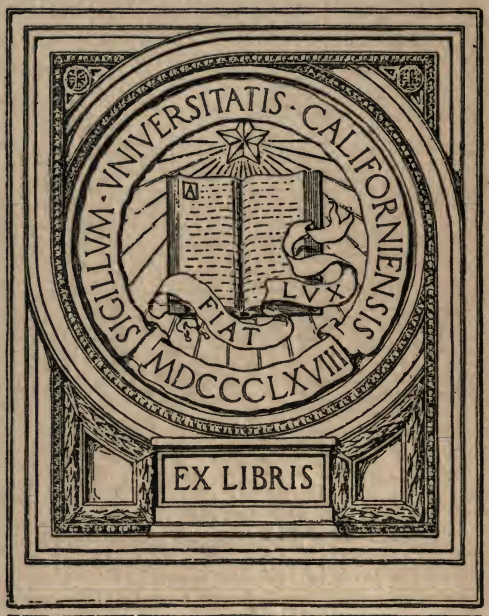
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SELF INSTRUCTION IN NAVIGATION

TO WHICH IS ADDED
SOME USEFUL MISCELLANEOUS
INFORMATION INCLUDING
ILLUSTRATIVE CUTS ON
"RULES OF THE ROAD"

BY

HENRY L. THOMPSON
MASTER MARINER
LATE LIEUTENANT, U. S. N. ('98)

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PREFACE.

The writer of this book has endeavored to eliminate higher mathematics from the navigational work and use plain English instead of formulæ that prove so confusing to the man who has not been educated along these lines; to such a one Bowditch might as well be written in Greek. The skilled navigators are requested not to criticise this work for it is not written for them, but for the ones who are struggling to inform themselves although meeting with indifferent success and much discouragement. It would seem that any such men might take up the study of navigation by means of this book, and if Chapters 1-6 are carefully followed, and studied, the results are bound to be good. Let those who think they can't get ahead because they haven't been as well educated as might be, take courage and start a systematic study of these pages beginning with the Day's Work. Don't worry over the formulæ in Art. 1 (a and b) for they will be found to work in all right when needed.

Chapter V is a practical illustration of how these various problems ought to be applied in practice on an ocean steamer and it is believed will prove helpful.

The mastery of the problems in this book may kindle a desire to go deeper which Bowditch can satisfy at any time; but for practical navigation it is not necessary, for there is enough here to take a ship anywhere in the world.

Chapters 7 and 8 have been put in more for the amateur than anyone else; at the same time, the motor boat man or yachtsman may investigate the whole book with profit to himself. The study of the Rules of the Road, both International and Inland, should be carried on with Chapter 7; and the letter of the rules thoroughly mastered, the Inland Rules are commonly known as the blue book, while the International are in Department Circular, No. 230, Department of Commerce.

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NOTE.

In correcting the observed altitude a good altitude correction table may be used in practice. In the 1914 edition of Bowditch, Table 46 for this purpose has been added; enter it with the height of the eye at the top and altitude at the side, the desired correction for sun or star is found at intersecting point; additional correction found at bottom of page to allow for change in semi-diameter.

If the navigator uses the American Nautical Almanac he will not now (1916) need to correct the declination or equation of time; they are given for every two hours of each day, and values for intermediate hours may easily be obtained by interpolation.

Use Bowditch in conjunction with this book for the tables referred to.

CHAPTER ONE.

Article 1 (a) Middle Latitude Sailing.

Case	Given	To Find	Solution
1	Both Lats. & Longs.	Dep. Course Dist.	Dep. = D. Lo. × Cos. M. L. Tan. C = Dep. ÷ D. L. Dist. = Sec. C. × D. L.
2	Both Lat. & Dep.	Course Dist. D. Lo.	Tan. C = Dep. ÷ D. L. Dist. = Dep. ÷ Sin. C. D. Lo. = Dep. ÷ Cos. M. L.
3	One Lat. C. & Dist.	D. L. Dep. D. Lo.	D. L. = Dist. × Cos. C. Dep. = Dist. × Sin. C. D. Lo. = Dep. × Sec. M. L.
4	Both Lats. & C.	Dep. Dist. D. Lo.	Dep. = D. L. × Tan. C. Dist. = D. L. ÷ Cos. C. D. Lo. = Dep. × Sec. M. L.
5	Both Lats. & Dist.	C. Dep. D. Lo.	Cos. C. = D. L. ÷ Dist. Dep. = Dist. × Sin. C. D. Lo. = Dep. × Sec. M. L.
6	One Lat. C. & Dep.	D. L. Dist. D. Lo.	D. L. = Dep. ÷ Tan. C. Dist. = Dep. ÷ Sin. C. D. Lo. = Dep. × Sec. M. L.

Article 1 (b) **Mercator Sailing.**

Case	Given	To Find	Solution
1	Both Lats. & Longs.	C. Dist. Dep.	Tan.C. = D. Lo. ÷ m. Dist. = Sec.C. × D. L. Dep. = D. L. × Tan. C.
2	Both Lats. & Dep.	C. Dist. D. Lo.	Tan.C. = Dep. ÷ D. L. Dist. = D. L. × Sec. C. D.Lo. = m. × Tan. C.
3	One Lat.C. & Dist.	Dep. D. L. D. Lo.	Dep. = Dist. × Sin. C. D. L. = Dist. × Cos. C. D.Lo. = m. × Tan. C.
4	Both Lats. & C.	Dist. Dep. D. Lo.	Dist. = D. L. ÷ Cos. C. Dep. = D. L. × Tan. C. D.Lo. = m. × Tan. C.
5	Both Lat. & Dist.	C. Dep. D. Lo.	Cos.C. = D. L. ÷ Dist. Dep. = Dist. × Sin. C. D.Lo. = m. × Tan. C.
6	One Lat. C. & Dep.	D. L. Dist. D. Lo.	D. L. = Dep. ÷ Tan. C. Dist. = Dep. ÷ Sin. C. D.Lo. = m. × Tan. C.

Note. To use any formula in these sailings find the case it is necessary to use by an examination of what is given and what it is desired to find, then do the work according to the form in Chapter 1, Article 2. To analyze a formula take for instance Case. 2, Mid. Lat. Sailing; it is readily seen that both Latitudes and Dep. are given to find the Course, Dist. and D. Lo.; obviously then the first unknown quantity is the Course; following along to the Solution there is found Tan. C. = Dep. ÷ D. L., i. e. the log. of the D. L. subtracted from the log. of the Dep. will leave the log. tangent of the true course (T. C.); so in the work form write in the Dep. and D. L. and pick out their logs; subtract them and the result is a tangent which being found in Table 44 will give the T. C. An explanation of one formula will apply to any used in this work; the only point to remember is that the sign × means add, and the sign ÷ means subtract.

DAY'S WORK.

Article 2.

Work Form Mercator's Sailing.

Comp. Courses	Var.	Dev.	Error	True Courses	Dist.	N	S	E	W

Lat. Left _____ Merid. parts _____ _____ _____ _____

D. L. _____

Lat. in _____ " " _____

m.

SOLUTION.

Dep. log.

D. L. log. _____ log.

T. C. Tan. Sec. _____ Tan.

Dist. Log.

m. Log. _____

D. Lo. Log.

Long. left

D. Lo. _____

Long. in

Middle Latitude Sailing.

Work Form.

Traverse Table as per Chapter 1, Article 2.

° ′ ″

Lat. left (N. or S.)

D. L. _____ "

Lat. in "

½ D. L. _____ (Add to lesser Lat., or subtract

Mid. Lat. from greater Lat.)

Use solution according to case required and work form, Chapter 1, Art. 2.

The work forms in this Article may be used for any case by changing the data in the Solution to meet the requirements.

For Turning Compass Points into Degrees.

Points	Degrees.			Points	Degrees		
	°	′	″		°	′	″
¼	2	48	45	4¼	47	48	45
½	5	37	30	4½	50	37	30
¾	8	26	15	4¾	53	26	15
1	11	15	00	5	56	15	00
1¼	14	03	45	5¼	59	03	45
1½	16	52	30	5½	61	52	30
1¾	19	41	15	5¾	64	41	15
2	22	30	00	6	67	30	00
2¼	25	18	45	6¼	70	18	45
2½	28	07	30	6½	73	07	30
2¾	30	56	15	6¾	75	56	15
3	33	45	00	7	78	45	00
3¼	36	33	45	7¼	81	33	45
3½	39	22	30	7½	84	22	30
3¾	42	11	15	7¾	87	11	15
4	45	00	00	8	90	00	00

Day's Work Described.

Art. 3. Correct each course for leeway, if any, turn the result into degrees, min., and sec. by means of Table in Art. 2 always counting number of points from N. or S. towards E. or W.

Example.

Course S. S. W. ½ W. = 2½ points found in the table to equal 28° 7′ 30″; turn min. and sec. into tenths (decimal) of a degree, thus: —

Divide 30″ by 60.		6) 30
Result, decimal of a min.		.5
The min. then are	7.5	
Which divide by 60,	result	6) 7.5
Decimal of a degree		.12

Course ready to use is S. 28.1° W. If second decimal place is over 5, use next highest tenth, rejecting second figure. This method of dividing by 60 is to reject the cipher and point off one more place, and may be used as short method either in arc or in time.

Enter course, in above form, in column marked **Comp. Courses,** with Var. and Dev. abreast in their respective columns. Deduce the error, enter it and apply to the comp. course — to the left if West, to the right if East, determined by standing in the center of the compass, in imagination, and facing towards the rim in the direction of the course — entering the resulting true course (T. C.) with the distance sailed. When all courses are entered, Dep. first and Current last, start at the top and enter Table 2, finding the degrees up to 45 at the top of the page, thence to 90° at the bottom. Find the distance in col. of dist., and opposite will be the Dif. of Lat. (D. L.) and Departure (Dep.) in their respective columns, taking their names from top or bottom of col., according as the degrees are found at top or bottom.

Example.

Suppose a course S. 57.6° E. Dist. 50 miles.

Enter Table 2 degrees at bottom, so cols. will be named from bottom.

D. L.		Dep.
27.2	57°	41.9
26.5	58	42.4
.7		.5

these differences are for 1° or ten-tenths; one-tenth will equal a division by 10, and for the required dif. or .6, multiply by 6, thus: —

.07	=	dif. for one-tenth
6		
.42	=	" six-tenths
		and
.05	=	dif. for one-tenth
6		
.30	=	" six-tenths

An examination of the D. L. shows that it is decreasing from 57° to 58°, consequently the cor. of .4 is subtracted from 27.2 = 26.8 the D. L. for 57°.6 course.

Dep. is seen to be increasing so the cor. of .3 is to be added to 41.9 = 42.2 the Dep. for this course.

Enter D. L. and Dep. in traverse table, taking care to observe the direction sailed. When all the courses have been handled in this manner, add up the N. S. E. and W. cols., subtract the lesser D. L. from the greater and the lesser Dep. from the greater, and the result is the D. L. (N. or S.) and Dep. (E. or W.) which has been made.

Place D. L. under Lat. left, first turning it into degrees and minutes if it is 60′ or over, and name it N. or S. as the case may be, also name Lat. left; if they are of unlike names, subtract; like names, add; result, Lat. in.

If it is desired to work in Mid. Lat. Sailing, divide D. L. by 2, placing result under Lat. in, and either add it to the smaller, or subtract from the greater, of the two Lats.

If it is desired to work in Mercator's Sailing, turn to Table 3, and pick out the Meridianal Parts for each Lat.; if both Lats. are on the same side of the Equator, subtract; different sides, add; result, Meridianal D. L. or m. Follow the formula in Case 2, Mercator's Sailing, Chap 1, Art. 1 (b). Fill in Dep. and D. L. in Work Form; pick out their logs from Table 42, subtracting log of D. L. from log of Dep. and the resulting log will be the tangent of the true course (T. C.); find this tan. in Table 44 and fill in T. C., taking the degrees from the top or bottom of the page, according as the name of tan. col. was taken from top or bottom. Find the sec. at same time and place abreast the tan. and again carry out tan. in line with sec.; over the sec., write in log of D. L.; the sum of these two logs will be the log of the dist. which find in Table 42. Fill in m in Work Form and find its log in Table 42 which add to tan. of T. C.; result log of D. Lo.

If the dist. run is short, or does not include much change in Lat. the Mid. Lat. sailing will be equally as good and may be done by inspection as follows: —

Enter Table 2 with Mid. Lat. as a course, find Dep. in col. of D. L. and opposite in col. of dist. will be the D. Lo.; in Table 2, find that place where D. L. and Dep. most nearly correspond, opposite col. of dist. will be the Dist. and the T. C. will be found (degrees at top or bottom) according as D. L. and Dep. cols. are named from top or bottom. Place D. Lo. under Long. left by turning it into degrees and minutes if 60′ or over, name it E. or W. in accordance with name of Dep. and having named Long. left, combine the two; like names add, unlike names subtract; resulting Long. to take name of the greater. It may be remarked that any of the Sailings may be worked by inspection.

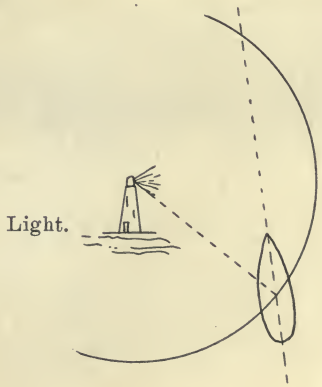
Note. Dep. course is first and is corrected for Var. and Dev. current course is last and is corrected for Var. only. To find a departure course, observe the bearing of a light or fixed point, correct this bearing and reverse it.

Article 3.

Position by Bearings.

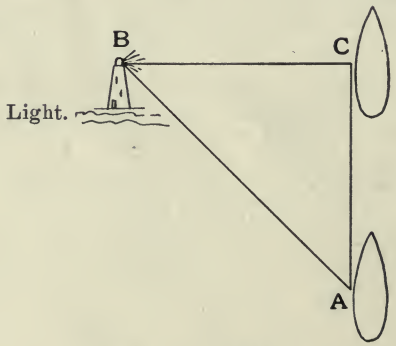
MAKING A LIGHT.

The officer of the deck, knowing he will make the land in his watch, has his list of lights handy, in order to obtain the visibility, and knowing the height of his eye above the sea in the location where his watch is to be stood, picks out beforehand, from Table 14, Bowditch, the correction for dip. Suppose he is running towards Boston and expects to make Highland Light; as soon as it appears clearly above the horizon, he takes a careful bearing across the compass, or better still with a pelorus, if he has one at hand, looks up the visibility in the light book and corrects it for dip, of course adding the correction because the visibility is given for the sea level and the ship's bridge may be forty feet above. Correct the obs. bearing for the Dev. of the compass on the course steered and lay it down on the chart; measure the dist. of visibility plus the cor. for dip from the light and where this cuts the line of bearing is the position of the ship. Being liable to error on account of refraction, this method is only a check and is not considered reliable; but in case it should shut in thick shortly afterwards, it would ease the "old Man's" mind a little if the officer of the deck could give him the "Fix."



FOUR POINT BEARING.

When the Highlands bears four points on the bow, note the time carefully, also the log if the speed is not accurately known, and hold the same course till the light is abeam: the distance run between the bearings is the distance off at the time of the beam bearing. Here also error may creep in, owing to tide or carelessness, the latter should not be, and the former may generally be judged fairly. If this position jibes with the first one and falls on the track, the officer may feel quite secure and is justified in the belief that he will make the Light-Ship about as he has figured. If he feels any doubt however, about his bearing being good, again note the time, when it is four points abaft the beam, and another check is established. In coasting where the lights are not too far apart, the speed over the bottom can be quite accurately established by dividing the total number of minutes between two lights by the distance, establishing the number of minutes it takes to run one mile; hence the distance off is found and is not apt to be much affected by tide under ordinary conditions. Of course if it is bad weather and the speed of the ship irregular and uncertain, this is not reliable. A point to be thought of is that a poor four point bearing is worse than none because it may give confidence in a false position. The careful navigator, however, is ever alert to the possibility of mistakes, and it is well for the young officer to remember that the over confident man may come to grief through neglecting to use some one, or all of these opportunities to place his ship.



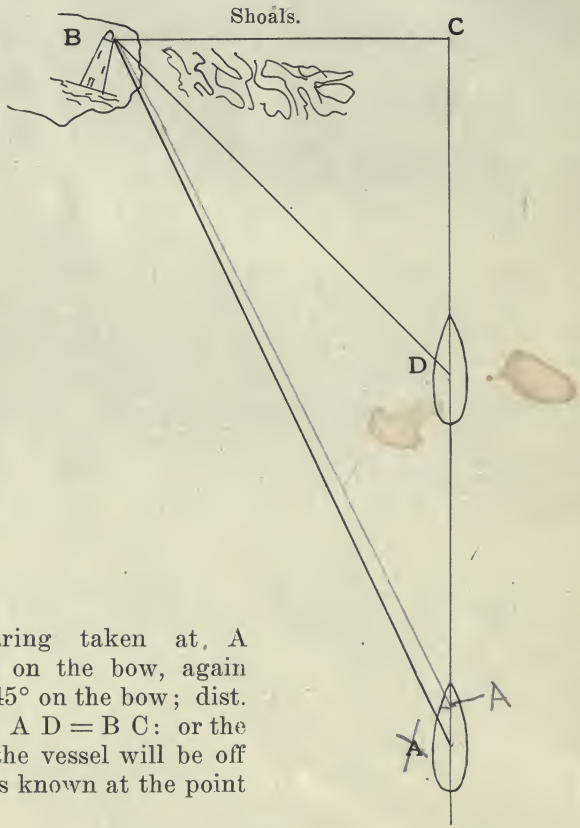
CROSS BEARINGS.

Once more may the position be obtained using the Highlands as a factor, provided the ship is far enough to the Southward to see The Race. If it is made, the officer of the deck immediately takes a bearing on it and as quickly as possible swings the sight vanes round to bear on the Highlands. Correct these bearings for the Dev. for course steered and plot them on the chart; the point of intersection is of course the position of the ship. Take careful bearings and if the Dev. is known, this method is very reliable if the angle is good; as nearly as possible to 90° is the best angle for cross bearings, but never less than 30°, nor more than 150°.

If the pelorus is used, set it for the magnetic head of the ship and the bearings will then not need correcting; also be particular that the ship is steady on her course. In using cross bearings, a third one may be used with these two if it comes inside the limits.

BY TWO BEARINGS.

A handy thing to remember is that if a bearing of a light is taken 26½° on the bow and again 45° on the bow, the run between these bearings will be the distance off the light when abeam. Try this in conjunction with the Four Point Bearing. It is a good thing to use if there are outlying dangers off this light for the navigator must assure himself **beforehand** that he is going to pass far enough off. There are other methods that are good if convenient tables are at hand, such as the Danger Angle taken with a sextant, any two bearings, etc., but it is not the purpose of the author to make this work cumbersome and these methods are easily learned in Bowditch or Lecky.



Bearing taken at A 26½° on the bow, again at D 45° on the bow; dist. sailed A D = B C: or the dist. the vessel will be off at C is known at the point D.

CHAPTER II.

Latitude.

Article 1. Meridian Altitude of Sun (☉)

Work Form.

		° ′ ″	h. m. s.		hrs.
Obs. Alt.	Long.	=		=	
Cor.					
h.	Ap.Dec. .		(N.orS.)	H. D.	
90	Cor.			Hrs.	
	Cor.Dec.		(N.orS.)	Cor.	
M.Z.D.	(N.orS.)				
Cor.Dec.	(N.orS.)	Dip. –		S.D. +	
Lat.	(N.orS.)	Ref. –		Par +	
				+	
				–	
				Cor. +	

To have work ready for noon, use the following: —

Case I. Lat. and Dec. same name, Lat. the greater
+90° + Dec. – Cor. – Obs. Alt.

Case II. Lat. and Dec. same name, Dec. the greater
–90 + Dec. + Cor. + Obs. Alt.

Case III. Lat. and Dec. opposite names.
+ 90 – Dec. – Cor. – Obs. Alt.

	Case I.			Case II.			Case III.			
	+90°	00′	00″	–90°	00′	00″	+90°	00′	00″	
Dec.	+23	27	22	+ 9	14	11	–18	50	49	
Cor.	–	13	21	+	8	59	–	12	2	
Constant	+113	14	1	–80	36	50	+70	57	9	
Obs. Alt.	–40	4	0	+81	15	30	–30	13	10	
Lat.	73	10	1 N.	0	38	40 N.	40	43	59 S	

Observe the lower limb of the sun in contact with the horizon, and apply the I. C. if any; result, Obs. Alt.

Turn the Long. into hours and decimal thus: —

Long. 70° 15′ 30″ divide by 15.
15 in 70 = 4 hrs., with a remainder of 10° =
600 + 15′ = 615 ÷ 15 = 41 min. 30 ÷ 15 = 2

Result Long. in time, 4 h. 41 m. 2 s. on the principle that 1 hour = 15°. Divide sec. and min. by 60 by short method of dropping the cipher and point off one extra place.

6) 2

6) 41.03

.68

As 8 is more than 5, reject it and call the tenths (.7) Long. in time = 4.7 hrs.

In practice, this part can be done in the head, and fill in the Work Form. Enter Page 1 of American Nautical Almanac for the date and pick out Ap. Dec. with its hourly dif. (H. D.) and the semi-diameter (S. D.) Multiply H. D. by the hrs. (or Long. in time) applying result to Ap. Dec. as Cor. according to this rule: In W. Long., if Dec. is increasing, add; decreasing, subtract; in East Long., vice-versa. Be particular to name the Dec.

Enter Table 14 of Bowditch and pick out Cor. for height of eye, or dip. In Table 20 A find ref., and in Table 16 Par. Fill these in the Work Form and the total Cor. will be found to be additive; apply it to Obs. Alt.; result C. C. A. or h. Subtract h. from 90° to find M. Z. D. (Meridian Zenith Distance) or in other words the dist. the sun is from the observer's zenith when on the meridian, and it is named opposite to the sun's bearing. Place Dec. under M. Z. D. and apply as follows: — Like names, add; unlike names, subtract. Result is the Lat., taking the name of the greater.

Note. — When the navigator works his morning sight and carries his position forward to noon the long. is sufficiently accurate to correct the dec. The Lat. is generally known to be either N. or S. and the obs. alt. will be known near enough to find the ref. and par.; hence the correction for the obs. alt. can be quite accurately figured beforehand; and all he needs to do is to see which case applies and work it up as far as the "Constant," when he is ready to apply his obs. alt. and give the Lat. to the captain promptly at eight bells. (See Case I, II and III at end of Work Form.)

Article 2. **Ex-Meridian Alt. of Sun.**

Work Form.

			H. D.		
Watch		Ap. Dec.	Hrs.		
C.–W.		Cor.			
Chro.		Cor. Dec.			
Cor.					
G. M. T.		Eq. T.	H. D.		
Eq. T.		Cor.	Hrs.		
G. Ap. T.		Cor. Eq.T.			
Long.		=hrs.	Dip. –	S. D.+	
L. Ap.T.			Ref. –	Par. +	
	12			+	
t.				–	
		Obs. Alt.		Cor. +	
		Cor.+		(Table 26)a =	
		h.		(" 27)at²=	
		at²+			
		H.			
		90			
		z.			
		d.			
		Lat.			
(at time of sight)					
D. L. to noon					
Noon Lat.					

The use of Tables 26 and 27 in Bowditch is confined to an interval from noon not greater than 26 min. though this problem may be worked reliably at a greater interval with other tables if at hand. This explanation, however, is that of the Bowditch method.

Care must be used in observing the alt. that the time is accurately noted on the watch, from which find chro. time by applying C-W and the chro. error applied will give G. M. T.; to this apply the Cor. Eq. T. from page 1 of the Almanac; result G. Ap. T. To this apply the Long. in time, subtracting if W. and the result is Local Apparent Time (L. Ap. T.) which subtracted from 12 hours will give the interval from noon, marked t, if L. Ap. T. is A. M.; if it is P. M., it will not be necessary to subtract from 12 hours as the time itself will equal t. Using the Work Form find the Ap. Dec. in page 1 of the Almanac and take H. D. at same time, also Eq. T. and its H. D. Correct the Dec. and Eq. T. for Long. as already described in Chap. II, Art. 1. Correct the Alt., finding value of h. Enter Table 26 with Dec. at top and Lat. at side, paying attention to their names, and at their junction will be a cor. in seconds which is = to a in Form; this is the variation in alt. in one min. from noon. Enter Table 27 with "t" at the top and "a" at the side and at their junction will be found at^2 or the correction to be applied + to the cor. alt. (h) to find the value of H.; or in other words H. is the merid. alt. for the meridian on at time of sight. The Lat. is then found by applying H. to 90°, etc., as explained in Chap. II, Art. 1. It must be remembered however, that this Lat. is for a time from noon equal to the value of "t" during which interval probably the ship has not been standing still, consequently the D. L. made must be applied in order to have the correct Lat. at Noon. This D. L. is readily found by inspection in Table 2 as explained in Chapter 1, Art. 2.

Article 3. By Mer. Alt. of Fixed Star.

Work Form.

G. M. T. Merid. Passage			Dec.
C.-W.			
Watch			Dip.–
			Ref.–
			Cor.–
	°	′ ″	
Obs. Alt.			
Cor.	–		
h.			
	90		
z.			(N. or S.)
d.			(N. or S.)
Lat.			(N. or S.)

From the table in Am. Nautical Almanac Supplement, find the time of merid. passage of the star, also its Dec. from table of Apparent Places. Compare the watch with G. M. T. and note the altitude at the moment of transit by the watch. Correct the Alt. for I. C. if any, to find the Obs. Alt. The cor. for Dip. and Ref. are to be taken from Tables 14 and 20 A. Apply this total cor. (always minus) to the Obs. Alt. From this point proceed as in Chap. II, Art. 1. In taking the Dec. from the Almanac sign + means North, and sign — means South. Care should be used in stellar observations to select a star whose merid. passage occurs in as good daylight as may be to enable the observer to see the horizon most distinctly, which cannot always be done except with Polaris. Frequently a star can be had in the North and one in the South at the same time. If the merid. passage does not occur just right, make an Ex-Meridian of it just the same as with the sun. If taking a morning sight, begin before daylight and bring the star down to the horizon while it is bright enough to do so easily; watch it every few minutes as it comes daylight, or until the moment of merid. passage; or

figure up the Lat. by D. R. and from this work backward to the alt. and set the sextant; unless quite an error has been made, the star may easily be found this way. This latter method is generally used in the evening twilight when it is desirable to observe the alt. as early as possible, or before the horizon grows indistinct. The alt. of a star is only corrected for Dip. and Ref. Obviously Semi-Diameter and Parallax would be so small as not to be practical in any navigational work.

Note. In all altitude corrections, see note in front of book for use of Table 46, 1914 edition of Bowditch.

Article 4. By Polaris (North Star).

Work Form.

			Dip.
L. M. Ast. T.			Ref. _____
Red. Table III			Cor.
G. Sid. T.			
Red. Table III	_____	Obs. Alt.	
L. Sid. T.		Cor.	_____
	_____	True Alt.	
H. A.		Cor.	_____
		Lat.	

This form is for the method described in the back of the American Nautical Almanac which is given so clearly that it is not deemed necessary to repeat it here. The tables for all corrections are given in the same part of the book. This method is sufficiently accurate for navigational purposes and is shorter than that given in Bowditch.

CHAPTER III.

Longitude.

Article 1 Time Sight.

	Hrs. Min. Sec.			H. D.
Watch		Ap. Dec.		Hrs.
C.–W.		Cor.		Cor.
Chro.		Cor. Dec.		
Error		P. D.	90	
G. M. T.				
*	12			
G. M. A. T.		Eq. T.		H. D.
	24	Cor.		Hrs.
Before noon.	= Hrs.	Cor. Eq. T.		Cor.
		Dip.–		S.D.+
	Obs. Alt.	Ref.–		Par.+
	Cor. +	–		+
	h.			–
	Lat.	Sec.		Cor.+
	P. D.	Cosec.		
	S. 2)			
	½S.	Cos.		
	h.			
	Rem.	Sin.		
			2)	

L. Ap.T.	Sin.	
Eq. T.		
L. M. T.		
*	12	
L.M.A.T.		
G.M.A.T.		
Long. in time		
	15	
Long.	E. or W.	
D. Lo.	E. or W.	Table 38
Noon Long.	E. or W.	Cor. for Lat. error

A M run; T. C. Dist.

Mid. Lat. D. L. Dep. D.Lo.

Compare the watch with chro. finding the watch error on G. M. T. (Greenwich Mean Time), then when the sun is as near the prime vertical as possible, or its azimuth is nearest to 90°, but so the altitude will be more than 6°, take an alt. of $\odot$ noting the time carefully on the watch; a good way being to begin the moment the alt. is taken and count thus: 1 and 2 and 3 and 4 and 5 — meantime, lowering the sextant and removing the watch from the pocket you are ready to note the seconds by the time you have counted 5 in this manner, deducting 5 s. from the number noted; it is then an easy matter to note the min. The old-fashioned deep water method of having a boy or two stationed along on deck to sing out Time, perhaps with the mate taking the sight from forward somewhere if she happens to be heading to the Eastward, meant a possible error of four or five seconds by the time the word reached the "old man" in the cabin noting the chro., and is impossible in a modern steamer, accuracy being the key note of up-to-date navigation. If more than one sight is to be taken, though one good one is as good

* If time is P. M., leave out this operation as it will already be Astronomical Time.

as a dozen, read off your alt. as quickly as possible and note it with the time; bring the sun down again, and repeat the same operation. Sometimes two sights are taken and used as in a Sumner; and again three sights and the mean of them and of the times is used although it is rather out of date to do so. Now prepare the data. To the watch time apply C-W. then the Chro. Error and the result is G. M. T.; if between midnight and noon, add 12 to the hours and subtract 1 from the date which reduces it to G. M. Astronomical T.; if it falls after noon, this calculation is unnecessary as G. M. T. is already Astronomical Time and it is also the time from noon with which to correct Dec. and Eq. T. If before noon, subtract it from 24 to find the interval from noon. Turn this interval into hours and decimals of an hour as explained in Chap. II, Art. 1.

Enter Page II of the Almanac for the nearest noon and pick out the Dec. and Eq. of Time with their H. D.'s which multiply by the interval from Noon. Apply these cor. according as the Dec. and Eq. of T. are increasing or decreasing and whether the time interval is before or after noon. Notice at top of Eq. of T. col. how it is to be applied to Ap. T. which will be found to be opposite to the way it is applied to mean time, and place the proper sign before it in order to know what to do with it when the proper time comes to use it. Find the Polar Dist. (p.) which is the dist. the sun is from the observer's nearest pole, by applying the Dec. to 90°, according to the following rule: Lat. and Dec. same name, subtract; different names, add. Correct the obs. alt. for Dip, Ref., S. D. & Par., and mark it h. Add together h. + Lat. + p., take the half sum and subtract h. Enter Table 44, find the secant of the Lat. cosecant of p., cosine of ½ S. and sine of Rem. Half the sum of these four logs will be the sine of the Hour Angle or L. Ap. T. taken from A. M. pr. P. M. col of Table 44, according as the time of sight was A. M. or P. M. Apply Eq. of T. and if the resulting L. M. T. is before noon, turn it into astronomical time by adding 12 to the hours, and it is a matter of course that whenever this is done and the date is needed to be used, subtract one from it. Bring down G. M. A. T. and subtract

the lesser from the greater, the result being the Long. in time which turn into degrees, etc., thus: —

	h.	m.	s.
Long.	4	41	2
	15		
	60		
	10	15	30
	70	15	30

Named E. or W. thus: G. M. T. best, Long. W.
G. M. T. least, Long. E.

Analysis

$4 \times 15 = 60°$

$41 \div 4 = 10$ with 1 rem.

m.

$1 \times 15 = 15'$

Sec.

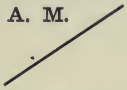
$2 \times 15 = 30''$

$70° \quad 15' \quad 30''$

On the principle that in 1 hour of time are 15° of Long.; in 4 min. of time, 1° of Long.; and in 4 sec. of time, 1′ of Long.

This reduction can also be made from Table 7 Bowditch; abreast 4 - 40 is 70° then abreast of 1 m. is 15′, and abreast of 2 s. is 30″; but it will be found in practice that the computation can be made while one is hunting up the table. Long. being found at time of sight, carry it forward to Noon by using the probable forenoon run in Mid. Lat. Sailing by Inspection as follows: Enter Table II with the T. C. and Dist., opposite in D. L. col. will be D. L. to be applied to Lat. used at sight and deduce Mid. Lat.; also the Dep.; with Mid. Lat. as a Course, enter Table II and find the Dep. in D. L., col., opposite in the Dist. Col. will be found D. Lo. Apply this to Long. at sight, and if the Lat. by Obs. at Noon agrees with the one used in the sight and afterwards carried forward, this Long. may be assumed to be correct. If, however, the Lat. is found to be in error, a cor. is to be taken from Table 38 Bowditch, which cor. for 1 mile of Lat. is to be

picked out and noted in the morning when the sight is worked. An examination of this table shows that the approximate Lat. is found at the top, sun's alt. and polar dist. at side and the cor. at the junction is the error in Long. due to 1′ error in Lat.; then if at Noon the Lat. is found to be 3′ in error Cor. x 3 = cor. to be applied to the Long. in A. M. further North further East; further South, further West; P. M., the opposite. If this is forgotten, it can be seen on the Sumner Line



that the further North the Lat. is, the Long. goes to the Eastward. This work being all done in the morning and the Lat. Constant established (see Work Form, Chap. II, Art. 1) nothing remains at Noon but to apply Obs. Alt. to the constant as already explained in said Art. and the cor. to the Long. for error in Lat. if any, and in a moment after eight bells, the navigator can hand the captain his position.

See note in front of book, explaining use of Table 46 (1914 edition of Bowditch), also finding declination and equation of time corrected for every two hours in editions of American Nautical Almanac since 1915.

Article 3 (a). **Sumner.**

Work Form.

W.
C.–W.
Chro.
Error
G.M.T.
12
G.M.A.T.
24
Int. = hrs.
h.
L. Sec.
p. Cosec.
2)
½s. Cos.
h.
½s-h. Sin.
2)
L.Ap.T. Sin.
Eq.T.
L.M.T.
12
L.M.A.T.
G.M.A.T.
15
Long.

D.L. D. Lo.

Sumner Line.

Ap.Dec. H.D.
Cor. Hrs.
Cor.Dec.
90
p.
Ap.Eq.T. H.D.
Cor. Hrs.
Cor.Eq.T

h.
L. Sec.
p. Cosec.
2)
½s Cos.
h.
½s-h. Sin.
2)
L.Ap.T. Sin.
Eq.T.
L.M.T.
12
L.M.A.T.
G.M.A.T.
15
Long.

Dep.

In any time sight it is just as well to apply the Eq. T. to G. M. T. which will give G. A. P. T. then the L. Ap. T. will be applied to G. Ap. T.

The computation is the same as for an ordinary time sight, only more of it. Assume a Lat. 10′ or 20′ each side of the D. R. Lat. and work with each, carrying them along together. Two positions will be the result which laid down on the chart will give the line of position and the point on that line of the nearest known Lat. will be the position of the ship. Or this line may be established by inspection of Table II, using a formula in Mid. Lat. Sailing. Enter Table II with Mid. Lat. as a course, find D. Lo. in Dist. Col., opposite in col. of D. L. will be found the Dep.; look for D. L. and Dep. to most nearly correspond and the degrees at top or bottom of page will be the direction of the Summer Line; and since this line is always at right angles with the Azimuth of the body, if the sights are taken when as near the prime vertical as possible, the line would run nearly N. and S. and it is readily seen that quite a large error in Lat. would not affect the Long. In practice it is found that an error of 30′ of Lat. would not make more than 15″ in Long.

(b) As one line does not establish a position, except that it is known to be somewhere in that line and is fixed by the nearest known Lat., it is desirable to have two lines as near at right angles as possible, then the point of intersection is the position. When two stars are available whose Azimuths differ about 90°, the resulting lines of position are excellent. If the sun is used, the two lines may be found by taking a sight in the morning and again in the afternoon, carry the A. M. line forward by D. R. to the time of the P. M. sight and plot the two on the chart.

(c) As has been stated, the line of position is always at right angles to the Azimuth of the body, consequently by finding the true Azimuth, the line of position may be at once laid down at right angles to it and without working the sight. This method is a little too lazy, however, to be conducive to accuracy.

Article 4. **By a Fixed Star.**

Work Form.

Chro.		R.A. ✶		
Slow		Dec. ★		
G.M.T.			90	
	12	p.		
G.M.A.T.				Dip.–
R.A.M.S.	Obs.Alt.			Ref.–
Red.Table 9	Cor.	–		
G. S. T.	h.			
	Lat.		Sec.	
	p.		Cosec.	
		2)		
	s.		Cos.	
	h.			
	s-h		Sin	
				2)
H.A. ±		E. or W.	Sin.	
R.A. ★				
L. S. T.				
G. S. T.				
Long. in time				
	15			
Long.		E. or W.		

To the Chro. time apply the error, finding G. M. T. and if A. M., turn into Astronomical Time by adding 12 to the hours.

From Page II of the almanac, find the sun's Right Ascension for the date, and from Table 9, the reduction, which is additive to mean time. Add together these three items and the result is G. S. T.

Take the R. A. from the almanac, table of star places, also pick out the Dec. and apply it to 90° by this rule to find the Polar Dist. (P.) If Lat. and Dec. are of different names, add; same names, subtract. Correct star's alt. for Dip. and Ref.; result marked h. Add together h., Lat. and p. and from the half sum subtract h. In table 44, find sec. of Lat., cosec. of p., cosine of the half sum and sine of the remainder. Half the sum of these four logs will be sine of the H. A., named E. or W. as the sight is A. M. or P. M. Convert this H. A. into sidereal time as follows: — Sidereal time is equal to the sum of the right ascension of the body and its H. A. subtracting 24 h. when the sum exceeds that amount. If the H. A. is E., find it W. by subtracting it from 24 h. and then add the R. A., or a shorter way is to mark the Easterly H. A. minus and the R. A. plus, and subtract; the result will be the same. Having found the local sidereal time (L. S. T.), bring down G. S. T. and subtract the lesser from greater, leaving the Long. in time which turn into degrees, minutes and seconds as explained in Art. I of this chapter. The Long. is named E. or W. by this rule: —

G. S. T. least, Long. E.
G. S. T. best, Long. W.

Note. — The H. A. of a star or planet is always taken from the P. M. column. The work in this Art. is also good for a planet, but it is not as good to use as the corrections vary, and the Dec. & R. A. must be very carefully corrected. A planet is next to the moon in the amount of change in the data.

CHAPTER IV.

Compass Error and Deviation.

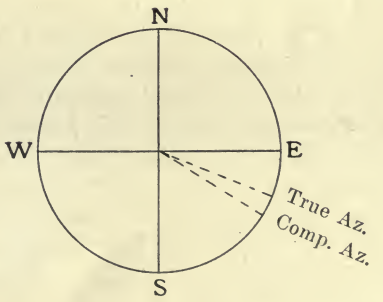
Article 1. **Azimuth.**

Work Form.

			H. D.
Chro.	Ap. Dec.		Hrs. _____
Error _____	Cor. _____		Cor.
G.M.T.	Cor.Dec.		
12	90		
G.M.A.T.	p.		
24		Dip.–	S.D.+
Int. from noon	= hrs.	Ref.– _____	Par.+ _____
		–	+
			–. _____
Obs. Alt.			Cor.+
Cor. + _____			
h.			Sec.
Lat.			Sec.
p.			
2) _____			
s.			Cos.
p. _____			
s-p.			Cos. _____
			2) _____
½ T. Az.			Cos.
2 _____			
T. Az.			
Comp. Az. _____			
Comp. Error			
Var. _____			
Dev.			

The azimuth may be taken at any time but the most favorable is when the altitude is low. It is often taken at the meridian passage using the apparent time of passage when the sun bears South (or North) but this bearing is apt to be unreliable. It is always a good plan to take a bearing at the time of taking a Long. sight, and can then be worked in unison, thereby saving some labor. If the problem is to be worked out, add together the corrected alt. Lat. and p., take the half sum and subtract p. If p. is greater than the half sum (s) the term s-p. will have a negative value but this does not affect the result. From Table 44 take the sec. of the Alt., sec. of the Lat., cos. of the half sum, and cos. of the rem. Half the sum of these four logs will be the cos. of half the true azimuth, reckoned from the N. in North Lat. and from the S. in South Lat. In North Lat. if the time is A. M., read the azimuth from North to East; if P. M., read it from North to West. Compare the True Az. with the Comp. bearing, subtracting the lesser from the greater, and the result is the compass error which is named E. or W., according as the True Az. is to the right or left of the compass Az. Example:

T. Az.	N.	120	E.
Comp. Az.	N.	125	E.
Error		5	W.



In making use of the above rule, imagine yourself standing in the center of the compass facing the rim, and looking in the direction of the bearings, it is obvious that the T. Az. falls to the left of the Comp. Az. therefore the error is W.

To find the Dev., take the var. from the chart, a pilot chart is the best, and apply it to the error with its opposite name; like names add, unlike names subtract, and give to the result the name of the greater. Example, suppose in the last case the var. was found from the chart to be 4° w.

Error,	5°	W.
Var.	4	E.
Dev.	1	W.

Now suppose the navigator is not going to work the problem, which as a matter of fact he never does if he has a good set of tables; we will return to the beginning and start differently. The most practical tables for the merchant ship navigator are Burdwood and its supplementary Davis; these tables are figured to every four min. of time. Work up your position by D. R. if you are not taking any other obs., and find the error of your watch on L. Ap. T., correct the declination; keep ship steady on her course and note the bearing of the sun, with shadow pin or azimuth mirror, at the same instant note the time. Apply the error of watch on L. Ap. T. and enter the azimuth table with the Ap. T. at side of page and Lat. and Dec. at top, taking care to see whether Lat. and Dec. are of the same or different names; at the junction of these columns will be found the True Az. If the Ap. T. doesn't jibe with the four min. intervals, the tabulated Az. must be corrected for the dif. between the two. Many times the navigator can help himself along by planning ahead a little, by looking at the table before taking the bearing and see where the Ap. T. falls, then note on a piece of paper the time the watch will show and wait for that min. before taking the bearing. If desirous of swinging ship on courses about to be steered during the night, and three or four dev. will be required, prepare a table ahead thus:

L. Ap. T.	Watch	P. H. Comp.	Stand	Comp. Az.
8.28				
.32				
.36				
.40				

Knowing how much the watch is fast or slow of Ap. T., it is easy to do the rest. It is often necessary to interpolate for Lat. if the Lat. falls half way between two degrees and the same for Dec., but practice will show the navigator how he can most easily do this; for instance, if a Dec. of 18° gave 79° 22′ and 19° gave 78° 20′, the dif. for 1° of Dec. is 1° 2′ = 62′; suppose the Dec. was about 18° 20′, the 20′ is ⅓ of a degree, and ⅓ of 62′ is 21′ nearly, so it would be seen at a glance that 21′ would have to be subtracted from 79° 22′ as the azimuth is decreasing from 18° to 19° of Dec. The same operation to interpolate for Lat. It may look to the beginner like quite a complication but it is really very easy after a little practice, and aboard a well regulated ship there is practice enough to be had in compass work.

Article 2. Amplitude.

Work Form.

Lat.	Sec.
Dec.	Sin.
T. Amp.	Sin.
Comp. Amp.	
Comp. Error	

There is little to be said about the work except to find the sec. of the Lat., the sine of the Dec. and add them together; result is the sine of the true amplitude reckoned from the E. or W. point. The compass error is then determined in the same manner as already described in the Azimuth problem. The observation is best taken when the sun is about one diameter above the visible horizon. If Burdwood's tables are used, the True Amp. is given for the Lat. and Dec.; also the apparent time of its rising and setting.

CHAPTER FIVE.

As a practical illustration of the manner in which the foregoing problems may be used in a day's navigational work aboard an ocean steamer, let a case be assumed in which a ship capable of steaming 23 knots, leaves her dock in New York at 10 a. m. (Eastern Standard time), March 18, 1914. and having discharged her Pilot, arrives at Ambrose Channel Lightship in Lat. 40° 28′ N. Long. 73° 50′ W. at 11.50 A. M., and her clock is set on Local Apparent Time (L. Ap. T.), which is found as follows: —

	h.	m.	s.	
E. Stand. Time	11	50	00	(75th Meridian)
	+ 5			
G. M, T.	16	50	00	
Long. in Time	4	55	20	
L. M. T.	11	54	40	
Eq. T.		−8	22	
L. Ap. T.	11	46	18	

Therefore the clock is retarded 3m., 42s.

Ship's chronometer showed 4 h. 55 m. 20 s. which was fast of G. M. T. 5 m. 20 s. and gaining 1.5 s. daily. Set course S. 76° E. for first turn on trans-Atlantic track, taken from Pilot Chart of May, 1912, in Lat. 40° 00′ N. Long. 70° 00′ W.

The formula to be used for this is found in Chapter I, Art. 1, Case 1 — Middle Lat. Sailing.

Lat. left	40°	28′ N.		Long. left	73°	50′ W.	
" of turn	40	00 N.		" of turn	70	00 W.	
D. L.		28		D. Lo.	3	50 = 230 miles	
		14					
Mid. Lat.	40	14					
D. Lo.		230	= 2.36173				
Mid. Lat.	40	14	= 9.88276				
Dep.		175.6	= 2.24449		2.24449		
D. L.		28	=		1.44716		1.44716
T. C. S.	80°	56′ E.	=		10.79733		.80249
Dist.		177.7	=				2.24965

Mean variation from pilot chart 10° W. Dev. from compass book for last voyage, 5° E. Error 5° W. Course by compass S. 76° E.

At 3 P. M., having run 74 miles, position by D. R. was found by inspection: —

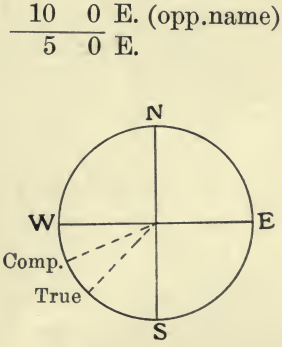
Lat. left	40°	28′ N.		Long. left	73°	50′ W.	
D. L.		12 S.		D. Lo.	1	35 E.	
Lat. in	40	16 N.		Long. in	72	15 W. = 4 h. 29 m	

Obs. a bearing of the sun with azimuth mirror, finding it to be S. 62° 51′ W. Chro. 8h. 9m. 2s. chro. fast 5m. 20s.

	h	m	s	
Chro.	8	9	2	
Fast		–5	20	
G. M. T.	8	3	42	
Long.	–4	49		
L. M. T.	3	14	42	
Eq. T.		–8	17	(Cor.)
L. Ap. T.	3	6	25	

Burdwood's Tables

T. Az.	N. 120°	9′ W.		
Comp. Az.	N. 117	9 W.		
Comp. Error	5	0 W.		
Var.	10	0 E.	(opp. name)	
Dev.	5	0 E.		



(True to the left, error is W.)

At 5 P. M., having sailed 120 miles on the T. C. S. 81° E., D. R. position was figured by inspection.

Lat. left	40°	28′	00 N.		Long. left	73°	50′	W.
D. L.		18	48 S.		D. Lo.	2	35	E.
Lat. in	40	9	12 N.		Long. in	71	15	W.

Obs. Alt. ⊙ 8° 44′. Height of eye 35 feet. Chro. 10h. 9m. 2s. fast 5m. 20s. Bearing by compass S. 86° 40′ W.

	h	m	s							
Chro.	10	9	2		Ap.Dec.	1°	10′	20.8″	S.	H.D. 59.29″
Error		−5	20		Cor.		−9	56.5		*10.06
G.M.T.	10	3	42	=10.06	Cor.Dec.	1	0	24.3	S.	35574
						90				5929
					p.	91	0	24		596.4574

Dip.	−5′	48″	S. D.	+16′	6″			
Ref.	−6	2	Par.	+	9			
	−11	50		+16	15		m. s.	s.
				−11	50	Eq.T.	8 22.68	H.D. .731
				+4	25	Cor.	7.35	*10.06
						Cor.Eq.T	+8 15.33	4386
								731
								7.35386

*See note in front of book relative to declination and equation of time being corrected for every two hours in American Nautical Almanac.

Obs. Alt.	8°	44′	00″		
Cor.		+ 4	25		
h.	8	48	25		
Lat.	40	9	12	Sec.	.11672
p.	91	0	24	Cosec.	.00007
2)	139	58	1		
½s.	69	59	00	Cos.	9.53440
h.	8	48	25		
(½s)– h.	61	10	35	Sin.	9.94256
	h;	m.	s.	2)	19.59375
L. Ap T.	5	10	18	Sin.	9.79687
Eq. T.		+8	15		
L. M. T.	5	18	33		
G. M. T.	10	3	42		
Lo. in time	4	45	9		
	15				
	60				
	11	15			
		2	15		
Long.	71	17	15 W.		

Azimuth.

h.	8°	48′	25″	Sec.	.00515
L.	40	9	12	Sec.	.11672
p.	91	0	24		
2)	139	58	1		
s.	69	59	00	Cos.	9.53440
p.	91	0	24		
s-p.	–21	1	24	Cos.	9.97008
				2)	19.62635
½ Az.		49°	26′	Cos.	9.81317
			2		
T. Az.	N.	98	52 W.		
Comp. Az.	N.	93	20 W.		
Error		5	32 W.		
Var.		10	30 E. (Opposite name)		
Dev.		4	58 E.		

A reference to the table of Meridian Transit of Stars in American Almanac Supplement showed the Officer of the Deck that ★ Sirius was on the meridian at 6 h. 59m. mean time and as it wasn't real dark and horizon seemed good, he took the altitude, finding it to be 33° 27′ 40″ at the moment of transit or 6 h. 37 m. 21s. by the ship's clock. Lat. D. R. 40° 4′ N. Long. 70° 29′ W. (Forward from 5 p.m. obs.)

5.00 to 6.37 P. M. sailed 37 miles. S. 81° 30′ E.

Lat. 5 P. M.	40°	9′	12′	N.
D. L.		5	30	S.
Lat. 6.37 P.M.	40	3	42	N.
	Dep.		36.5	
L.M.T. of Transit	6	59	00	
Long.	4	41	56	
G. M. T. of Transit	11	40	56	
Eq. T.		−8	15	
G. Ap. T. of Transit	11	32	41	
Long. of Dep. point	4	55	20	
Transit by clock	6	37	21	

Long, 5.00 P. M.	71°	17′		W.
D. Lo.		48		E.
Long. 6.37 P. M.	70	29		W.
	4	41	56	
★ Dec.	16°	35′	51″	S.
Obs. Alt. ★	33	27	40	
Cor.		−7	16	
h.	33	20	24	
	90			
z.	56	39	36	N.
d.	16	35	51	S.
Lat.	40	3	45	N.

The Officer of the Deck, finding from the obs. position that he will reach the first turn in his watch, figures up the course and distance to the turn.

6.37 P.M.. Position to Turn { Lat. 40° 00′ N. / Long. 70 00 W.

Lat. 6.37	40°	3′	45″	N.
Lat. of Turn	40	0	00	N.
D. L.	0	3	45	S.

Long. 6.37	70°	29′	W.
Long. of Turn	70	00	W.
D. Lo.	0	29	E.

T. C. S. 81° E. Dist. 23 miles. Dep. 22.2. Therefore knowing that it is just one hour's run and that at 7.35 the Turn will be arrived at, he figures up the course and distance to the second turn.

1st Turn { Lat. 40° 00′ N. / Long. 70 00 W.

Lat. 1st Turn	40	00	N.	
Lat. 2d "	38	20	N.	
D. L.	1	40	S.	=100 miles
		50		
Mid. L.	39	10		

2d Turn { Lat. 38° 20′ N. / Long. 50 00 W.

Long., 1st Turn	70	00	W.
Long., 2d Turn	50	00	W.
D. Lo.	20	00	E. =1200 miles

T. C. S. 84° E. Dist. 940 miles. Dep. 933 miles. Mean Var. till next noon 14° 30′ W. Dev. 5° 30′ E. Error 9° W. Compass course S. 75° E.

As the increasing var. will run her to the Northward of the track, he prepares a slip for the Captain, who orders course altered to S. 75° E. at 8 P. M.

At 10 P. M. D. R. position of next noon was worked.
T. C. S. 84° E. Dist., 360 miles.

Lat. 7.35	40°	00′	N.	Long. 7.35 P.M.	70°	00′	W.
D. L.		37	S.	D. Lo.	7	45	E.
Noon Lat.	39	23	N.	Long. Noon	62	15	W.
½ D. L.		18				4 h.	9 m
Mid. Lat.	39	41					

	h	m	s
Ship's clock	10	00	00

D. Lo. 465 miles

	h	m	s	
Chro.	3	9	2	
Fast		−5	21	
G.M.T.	15	3	41	(Add 12 hours)
Eq. T.		−8	2	(Cor. for Gr. time next noon)
G. Ap. T.	14	55	39	
Noon Long.	4	9	00	
L. Ap. T.	10	46	39	(For noon)

From this work, the clock is found to be 46 m. 39 s. slow. 11 P. M., advanced clock 46 m. 39 s. to L. Ap. T. for next noon, and sent a slip to the Chief Engineer and Chief Steward.

Mar. 19th, 5 A. M., D. R. position was worked, not forgetting the allowance of 46 m. 39 s. advance in the clock. T. C. S. 84° E. Dist. 197 miles.

Lat. 7.35 P.M.	40°	00′	N.	Long. 7.35 P.M.	75°	00′	W
D. L.		21	S.	D. Lo.	4	15	E.
Lat. 5.00 A.M.	39	39	N.	Long. 5.00 A.M.	65	45	W.
Dep. 195.9				D. Lo. 255		4h. 23m.	

Obs. Alt. ★ Polaris 38° 59′ Chro. 9 h. 22 m. 23 s.
Chro. fast 5 m. 21 s. Height of Eye, 35 ft.

	h	m	s
Chro.	9	22	23
Fast		−5	21
G. M. T.	9	17	2
	12		
G. M. A. T.	21	17	2
Long.	4	23	
L. M. A. T.	16	54	2
(Mar. 18)			

	h	m	s
L.M.A.T.	16	54	2
Red. Tab. III		2	47
G. S. T.	23	40	48
Red. for Long			+43
	40	38	20
	24		
L. Sid. T.	16	38	20
	25	28	36
H. A. ★	8	50	16

Dip.	−5′	48″
Ref.	−1	12
Cor.	−7	00

Obs. Alt. ★	38°	59′
Cor.		−7
True Alt.	38	52
Cor. Tab. I		+47
Lat. 5.00 A.M.	39	39 N.

At the instant of taking the Alt. of Polaris, another officer observed the Alt. of ★ Altair in the East, finding it to be 38° 4′ 45″. Chro. 9 h. 22 m. 23 s. Chro. fast 5 m. 21 s. Height of eye, 35 feet.

	h	m	s
Chro.	9	22	23
Fast		−5	21
G.M.T.	9	17	2
	12		
G.M.A.T.	21	17	2
R.A.M.S.	23	40	48
Red.(Tab.9)		3	30
	45	1	20
	24		
G.S.T.	21	1	20

	h	m	s	
R. A. ★	19	46	35	
Dec.	8	38	25	N.
	90			
p.	81	21	35	

Obs.Alt.	38°	4	45	Dip.	−5	48′
Cor.		−7	00	Ref.	−1	11
h.	37	57	45	Cor.	−6	59
L.	39	39	00	sec.	.11353	
p.	81	21	35	cosec.	.00496	
2)	158	58	20			
s.	79	29	10	cos.	9.26120	
h.	37	57	45			
s-h.	41	31	25	sin.	9.82147	
					2)19.20116	
H. A.	−3	7	57	E.	sin.	9.60058
R. A. ★	+19	46	35			
L. S. T.	16	38	38			
G. S. T.	21	1	20			
Long. in time	4	22	42			
	15					
	60					
	5	30				
		10	30			
	65	40	30	W.		

As a result of these two observations at the same moment, the exact position is obtained without an element of D. R. entering in. At sunrise occurring at 6 h. 3 m. L. Ap. T., an amplitude should be observed; preparing for this, the Officer of the Deck finds his approximate position at that time will be Lat. 39° 36′ N. Long. 65° 6′ W. Var. 15° W. Dev. (probably) 6 E. T. C. S. 84° E. Dist., 30 miles.

Lat. 5 A.M.	39°	39′ N.		Long. 5 A.M.	65°	40′ W.
D. L.		3 S.		D. Lo.		39 E.
Lat.	39	36 N.		Long.	65	1 W.
Dep. 29.8			D. Lo. 39		4 h. 20 m. 4 s.	

	h.	m.	s.
L. Ap. T. Sunrise	6	3	
Long.	4	20	4
G. Ap. T.	10	23	4
D. R., Noon Long.	4	9	0
Ship's Clock	6	14	4

Therefore at 6 h. 14 m. ship's time, the bearing of the rising sun when one diameter above the horizon was taken and found to be E. 10° 30′ S.

BURDWOOD'S TABLES.

T. Amp.	E.	1°	18′	S.	
Comp. Amp.	E.	10	30	S.	
Error		9	12	W.	
Var.		15		E.	(Opposite name)
Dev.		5	48	E.	

BY COMPUTATION.

Lat.	39°	36′	Sec.	.11322
Dec.	0	48	Sin.	8.14495
T. Amp. E.	1	2 S.	Sin.	8.25817

Knowing the exact Dev., the obs. position at 5 A. M. is carried forward to 8 A. M. Var. 14° 50′ W. T. C. S. 84° E. Dist., 69 miles.

Lat. 5 A.M.	39°	39′ N.		Long. 5 A.M.	65°	40′ W.
D. L.		7 S.		D. Lo.	1	29 E.
Lat. 8 A.M.	39	32 N.		Long. 8 A.M.	64	11 W.
Dep.	68.6			D. Lo.	89	

The Officer prepares a slip containing obs. position 8 A. M. and compass error sending it to the Captain, when he turns out.

At 8 A. M., a sight was taken, also a compass bearing. The obs. alt. found to be 20° 35′. Chro. 0 h. 22 m. 23 s. Chro. fast 5 m. 21 s. Height of eye, 35 feet. Desiring to establish the Sumner Line from this sight, the Lats. are assumed 10′ each side of the observation. Comp. Az. N. 118° 16′ E.

Chro.	00h.	22m.	23s.	
Fast		−5	21	
G. M. T.	00	17	2	= 0.29

Ap. Dec.	0°	46′	37.7″	S.
Cor.		−0	17.2	
Cor. Dec.	0	46	20	S.
	90			
p.	90	46	20	

H. D. 59.3″
Hrs. .29
5337
1186
17.197

(46)

Dip.	−5′	48″	S. D.	+16′	6″
Ref.	−2	33	Par.	+	8
	−8	21		+16	0
				− 8	
			Alt. Cor.	− 8	

Obs. Alt.	20°	35′	00
Cor.		+8	00
	20	43	00

Eq. T. +8m. 5s.

H. D. .738s.
Hrs. .29
6642
1476
.21402
(too small to use)

h.	20	43	00			20°	43′	00″		
L.	39	22	00	Sec.	.11176	39	42	00		.11385
p.	90	46	20	Cosec.	.00004	90	46	20		.00004
	2)150	51	20			2)151	11	20		
s.	75	25	40	Cos.	9.40070	75	35	40		9.39582
h.	20	43	00			20	43	00		
s.–h.	54	42	40	Sin.	9.91182	54	52	40		9.91272
	h.	m.	s.		19.42432	h.	m.	s.		19.42243
L. Ap. T.	7	51	48	Sin.	9.71216	7	52	24		9.71121
Eq. T.		+8	5				+8	5		
L. M. T.	7	59	53			8	00	29		
	12					12				
L. M. A. T.	19	59	53			20	00	29		
G. M. A. T.	00	17	2			00	17	2		
Long. in Time	4	17	9			4	16	33		
	15					15				
	60					60				
	4	15								
		2	15			4	8	15		
Long.	64	17	15	W.		64	8	15	W.	

D.L. 20′ D. Lo. 9′ Dep. 7′ Sumner Line 19°.

Long. is 64° 12′ 30″ W., corresponding to nearest known Lat. on the line.

True Az. at right angles to Sumner Line N. 109° 10′ E.

True Az. from Tables	N.	109°	8′	E.
Compass Az.	N.	118	16	E.
Compass Error		9	8	W.
Var.		15	40	E. (Opposite name)
Dev.		6	32	E.

Forenoon run. T. C. S 84° E. Dist. 92 miles.

Lat. 8 A.M.	39°	32′	N.
D. L.		10	S.
Noon Lat.	39	22	N.

Dep. 91.5′ D. Lo. 118′

Long. 8 A.M.	64°	12′	30″	W.
D. Lo.	1	58	00	E.
Noon Long.	62	14	30	W.

4 h. 8 m. 58 s. = 4.15 hrs.

	+90°	00′	00″	
	− 0	42	24	
	+89	17	36	
		− 9	33	
	+89	8	3	
Obs. Alt.	−49	45	0	
Lat.	39	23	0	N.

Ap. Dec.	0°	46′	30″	S.
Cor.		−4	6	
Cor. Dec.	0	42	24	S.

(The work to this point is done in the morning.)

Long.	62°	14′	30″	W.
Cor.		1	18	E.
Long.	62	13	12	W.

Dip.	−5′	48″	
Ref.	−0	51	
	−6	39	

(Long. Cor. for Lat. error. Table 38. 1.3′
Noon Lat. is 1′ N. of D. R.; cor. to the E.)

H. D.	59.29″		
	4.15		
	29645		
	5929		
	23716		
Cor.	246.0535		

S. D.	+	16′	5″
Par.	+		7
	+	16	12
		−6	39
Cor.	+	9	33

To illustrate the Ex. Merid. problem, about 15 or 20 min. before noon, the Alt. is taken and time noted.

	h.	m.	s.								
Chro.	4	00	34		Ap. Dec.	0°	46′	30″	S.	H. D.	59.29″
Fast		–5	21		Cor.		–4	6		hrs.	4.15
G. M. T.	3	55	13		Cor. Dec.	0	42	24	S.		246.0535
Eq. T.		–8	2								
G. Ap. T.	3	47	11	hrs.			m.	s.			s.
Long.	4	8	5	= 4.15	Eq. T.		8	4.9		H. D.	.74
L. Ap. T.	11	38	13		Cor.			–3			4.1
	12				Cor. Eq. T.		8	1.9			74
t.	00	21	47								296
											3.034

Obs. Alt.	49°	25′	00″			Dip.	−5′	48″	S. D.	+ 16′	5″
Cor.		+9	33			Ref.	−0	51	Par.	+	7
h.	49	34	33				−6	39		+ 16	12
at²		+18	58	(Table 26)a	= 2.4′					− 6	39
H.	49	53	31	(Table 27)at²	= 18′ 58″				Cor.	+9	33
	90										
z.	40	6	29 N.								
d.	0	42	24 S.								
Lat.	39	24	5 N.	(At time of sight.)							
D. L. to noon		1	0 S.								
Noon Lat.	39	23	0 N.								

Lat. Light-ship	40°	28′ N.		Long. Light-ship	73° 50′ W.
Lat. in	39	23 N.		Long. in	62 13 W.
D. L.	1	5=65′		D. Lo.	11 37 E.
½ D. L		32			697′
Mid. Lat.	39	55			

CASE I. MID. LAT. SAILING.

D. Lo.	697	= Log.	2.84323		
Mid. Lat.	39 55	= Cos.	9.88478		
Dep.	534.6	= Log.	2.72801		
D. L.	65	= Log.	1.81291		1.81291
T. C.	S. 83° 4′ E	= Tan.	10.91510		.91824
List.	538.5	= Log.			2.73115

Noon position. Lat. 39° 23′ N. Long. 62° 13′ W.

T. C. made good S. 83° 4′ E. Dist., 538.5 miles.

D. Lo. 11° 37′ = 46 m. 28 s.

Length of day, 23 h. 13 m. 32 s. Additional time from the lightship to noon, Mar. 18, 13 m. 42 s. Total time, 23 h. 27 m. 14 s.

Average speed, 22.9 knots.

To the Next Turn.

Lat. in	39°	23′	N.	Long.	62°	13′	W.
Turn	38	20	N.	Larn	50	00	W.
D. L.	1	3	S. = 63′	D. Lo.	12	13	E. = 733′
½D L..		31					
Mid. Lat.	38	51					

D. Lo.	733′	=	Log.	2.86510	
Mid. Lat.	38° 51′	=	Cos.	9.89142	
Dep.	570.9	=	Log.	2.75652	
D. L.	63	=	Log.	1.79934	1.79934
T. C.	S. 83° 42′ E.	=	Lan.	10.95718	.95966
Dist.	574.1 miles.	=	Log.		2.75900

Mean Var. 18° 45′ W.; Dev. 6° 30′ E.; Error 12° 15′ W.; Altered course (a.c.) to S. 71° E.

CHAPTER SIX.

Definitions — Navigational Terms.

Latitude (Lat.) — The distance N. or S. of the Equator.

Longitude (Long.) — The distance East or West of a given Meridian called the Prime Meridian. The meridian of Greenwich has been generally adopted.

Difference of Latitude (D. L.) — The distance in a N. or S. direction between any two points on the Earth's surface.

Difference of Longitude (D. Lo.) — Is the arc of the Equator intercepted between two meridians; measured in degrees, minutes and seconds.

Departure (Dep.)— The actual distance sailed in an East or West direction. Also the last known point left in dead reckoning.

Dead Reckoning (D. R.) — Guess work. Keeping the run of the ship by her courses and distances; always of doubtful accuracy, yet necessary.

Day's Work — The problem of D. R. which includes the record of the ship's run for 24 hours, the Traverse Table being the Compass Courses, Variation, Deviation and Leeway; True Courses, Distances and the North, South, East and West columns of D. L. and Dep. From this is worked the ship's position by any of the various sailings.

Variation (Var.) — That part of the Compass Error due to the difference in positions of the geographical and magnetic poles of the earth. The amount of the Var. depends on the angle between these two poles at the position of the observer which changes with the locality and the year.

Deviation (Dev.) — That part of the Compass Error due to masses of magnetic metal within the ship itself.

Local Attraction — That part of the Compass Error due to natural magnetic attraction in the vicinity of the vessel.

Compass Error — The difference between the compass and the true direction; or its total error.

True Course — Is the compass course corrected for all errors; Westerly Error to the left; Easterly to the right.

Magnetic Course — Is the compass course with all errors applied except the Variation; courses taken from the chart are Magnetic if the inner compass is used.

Zenith — Is the point in the heavens directly over the observer's head.

Celestial Equator or Equinoctial — Is the great circle formed by extending the plane of the Equator until it intersects the celestial sphere.

Declination — Is the distance of a heavenly body from the Equinoctial either N. or S. N. declinations may be regarded as positive (+) and S. declination as negative (—).

Polar Distance (P. D.) — Is the distance of a heavenly body from the pole nearest the observer.

Altitude (Alt.) — Is the distance of a heavenly body above the horizon.

Zenith Distance (Z. D.) — Is the distance of a heavenly body from the zenith.

Hour Angle —Is the angle at the pole between the meridian of the observer and the hour circle passing through the body.

Hour Circles — Are formed by extending the planes of the terrestrial meridians until they intersect the celestial sphere.

Azimuth — Is the bearing of a heavenly body measured from N. or S. towards E. or W. according as the Lat. is N. or S. and the position of the body E. or W. of the meridian.

Amplitude — Is the bearing of a body in the horizon.

Ecliptic — Is the path the sun appears to move in by reason of the annual revolution of the earth.

Equinoxes — Are those points on the Celestial Equator where the sun seems to cross it in changing declination. The point of crossing from Southern to Northern declination is the Vernal Equinox, also designated as the First Point of Aries and is used as an origin for reckoning right ascension.

Right Ascension — Is the celestial longitude of a heavenly body measured from the First Point of Aries Eastward through 24 hours.

Great Circles — Divide the Earth into two equal parts.

Small Circles — Divide the Earth into two unequal parts.

Meridians — Are great circles passing through the poles, and are used in measuring Long.

Parallels — Are small circles extending around the Earth parallel to the Equator, and are used for measuring Lat.

Equator — Is a Great Circle extending around the Earth midway between the poles, at right angles to the meridians.

Prime Meridian — Any meridian agreed upon as a unit from which to reckon Long.

Observed Altitude (h.) — The altitude of a heavenly body as read from a sextant.

Index Correction — An error of the sextant that ought not to be allowed to remain; but if it appears it must be applied to h.

Dip — A correction to be subtracted from h. owing to the height of the eye above sea level.

Refraction (Ref.) — A correction to be subtracted from h. owing to the rays of the sun being deflected by the atmosphere.

Parallax (Par.) — A correction to be added to h. changing it from the surface of the Earth to its center.

Semi-Diameter (S. D.) — A correction to be applied to h. if it is of the sun or moon. Additive if the lower limb is observed; subtractive if the upper. It corrects h. to the center of the body.

Apparent Time or Solar Time — Is the hour angle of the center of the sun. Owing to lack of uniformity of the sun's motion this time cannot be used as a standard.

Mean Time — Is the hour angle of the mean sun, a fictitious body invented for the purpose of overcoming the irregularities of the real sun; and given a uniform motion. The two suns coincide at the First Point of Aries.

Equation of Time — The difference between apparent and mean time.

Sidereal Time — Is the hour angle of the First Point of Aries.

Astronomical Time — Commences at noon of the civil day of the same date, is reckoned from 0 h. to 24 h. The civil day begins 12 hours before the astronomical day.

CHAPTER SEVEN.

CHARTS.

Navigation by this means is very simple as well as very useful, and a careful examination of the chart of a locality will frequently uncover to the observer facts hitherto unknown to him. In using the U. S. Government charts, it is well to remember that the soundings outside the dotted surfaces are expressed in fathoms and are referred to mean low water, while a shoal, rock, or reef will be shown by a dotted surface with the depth of water in feet. Strong tides are indicated by little arrows, the direction of the arrows showing the set. Where heights are expressed, such as on a bold mountainous coast, they are in feet from mean high water mark. Curves are generally shown on general charts at 50 and 100 fathoms and often up to greater depths, enabling a navigator to follow a line of soundings in the thick weather, thus checking his position. To find a course and distance by chart, indicate by a pencil dot the position of the vessel and another at the point aimed at; place the parallel rule with the same edge cutting both points and walk it to the nearest compass rose and the point of the compass touched by the edge of the rule, when it cuts the center, is the course, taking care to read it from the inside compass which gives the magnetic direction; the outside ring is the true direction — the variation changes with the locality. With the dividers spread between the points measure on the scale, or on the division at sides of chart, not at top or bottom, to find the distance in nautical miles. If the distance is large, spread the dividers to a convenient distance and step off between the points.

Rules of the Road.

AIDS TO MEMORY.

BY THOMAS GRAY.

When both side lights you see ahead,
Port your helm and show your Red,
Green to Green, or Red to Red,
Perfect safety — go ahead!

If to your starboard Red appear,
It is your duty to keep clear;
To act as judgment says is proper: —
To port, or starboard, back, or stop her!

But, when upon your port is seen
A steamer's starboard light of Green,
There's not so much for you to do,
For Green to port keeps clear of you.

Both in safety and in doubt,
Always keep a good lookout.
In danger with no room to turn,
Ease her! Stop her! Go astern.

If close hauled on the starboard tack,
No other ship can cross your track;
If on the port tack you appear,
Ships going free must all keep clear;
While you must yield, when going free,
To sail close hauled, or on your lee.
Both free with wind on different sides,
Art. 17 C. your case decides.
And if you have the wind right aft,
Keep clear of every sailing craft.

PRACTICAL ILLUSTRATIONS

Article 1.

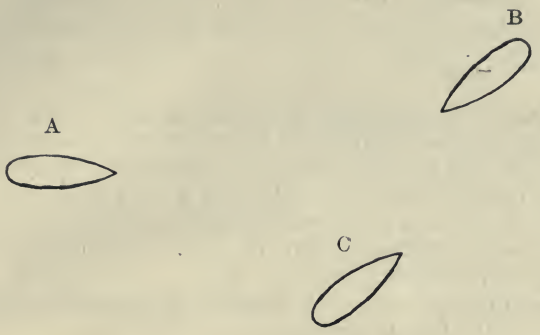
The duty of each is plain, blow 1 whistle, port the helm and swing to starboard, passing on each other's port hand. This is done when both lights are seen on each steamer at night; or when the masts of each are seen to be in a direct line in the day time. Either vessel may blow the whistle first.

If however, their courses are so far to starboard of each other, but on parallel lines, as to render passing on that side safe, each continues on his course, and if whistles are exchanged, the two blast signal is used.

Article 2.

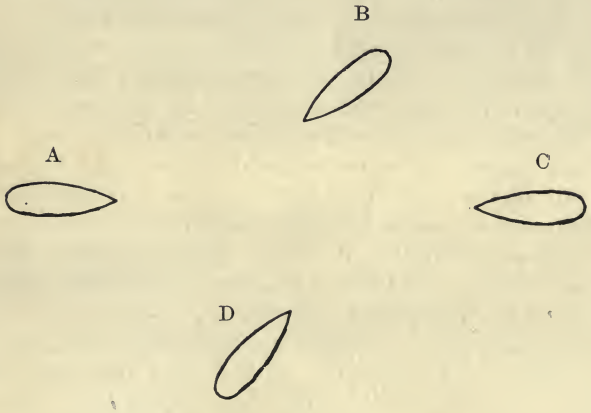
B. has A. on his starboard side, therefore A. has right of way. B. blows 1 whistle which A. answers with 1; B. then ports his helm and stops and backs if necessary. A. maintains his course and speed.

This may be complicated by the entrance of C.



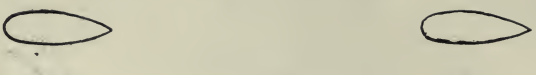
A. still has the right of way over B. but C. has it over A. B. may blow 1 whistle which may be answered by both A. and C.; then A. blows 1 to C., who answers it. A. ports his helm to go around the stern of C. B. ports his helm in order not to cramp A. C. continues on but may port a little or slow down or both, in order not to shave B. too closely.

It may be complicated still further by D.



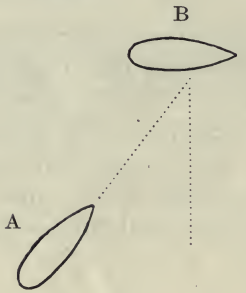
This looks bad but it isn't, provided everybody does the shipshape thing. All hands may blow 1 whistle and port; but lest there may be a greenhorn in one boat, it would be the best judgment for them to stop and back until whistles are exchanged and understood.

Article 3.



A B

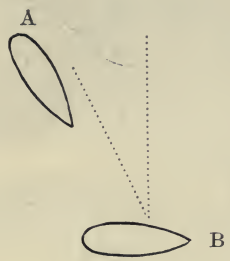
Here A. is supposed to be the faster of the two, consequently blows 1 whistle if he wishes to pass on B.'s starboard side or two whistles on the port side. Whichever signal is given, is answered by B. and A. is justified in passing. If however, B. sees some reason that A. doesn't which would render such passing unsafe, B. gives the danger signal of several short blasts, not less than 4, whereupon A. must stop and keep astern of B. until B. is ready for A. to pass; when B. will give the signal.



Still assuming A. to be the faster, this is a bad situation. The law says that any vessel coming up on another vessel from a direction more than two points abaft her beam is an overtaking vessel; to be determined in the night by a sight of her side lights; but if in the day time a doubt exists as to the bearing, she must consider herself an overtaking vessel and act accordingly. It sounds good in theory but the trouble is nobody ever takes a bearing to determine whether or not he is an overtaking vessel.

In the diagram, A. is without doubt an overtaking vessel, but place her between the dotted lines and as far from the beam bearing as possible and what happens? No one can tell exactly by his eye just which side of the line he is, and as stated above, a bearing is rarely taken. In the diagram A. says he is forward of the line and holds his course and speed because in a crossing situation he has the right of way; B. says A. is certainly an overtaking vessel and pays no particular attention to him, believing A. knows his business and will slow down and cross his stern; neither one takes

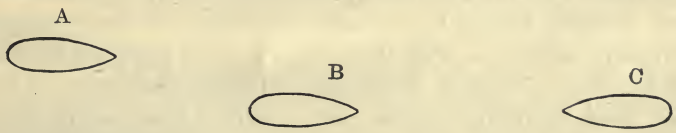
a bearing and presently they come together with each one claiming that he observed the rules, and believing it too. Always proceed with caution in this situation, and if in any position abaft the beam of the other vessel, give him the benefit of the doubt.



Here, however, it doesn't matter, because A must keep out of the way whether it be an overtaking or a crossing position.

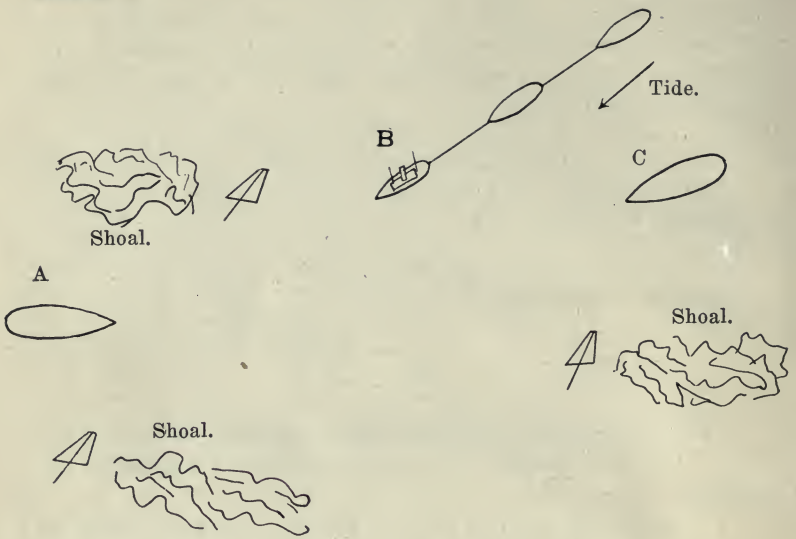
If A. should happen to be a sailing vessel, it makes no difference, for in the overtaking situation, if a sailing vessel happens to be faster than the steamer, it is well to remember that Art. 24 applies and takes precedence over Art. 20. There are men sailing boats who have overlooked Art. 24, and believe that there is no situation in which a sailing vessel shall keep out of the way of a steamer.

Article 4.



In this situation it looks at first glance as though A would pass B. on his port hand, but suppose C. hasn't seen A. and follows the law by holding to that side of the channel on his own starboard hand, gives B. 1 whistle and ports his helm? A mix-up may occur. Therefore the best thing A. can do is to give B. 1 whistle and if answered with 1 to port his helm, passing B. on his starboard hand; by so doing, he gives C. the opportunity to observe the law. Better still for A. to stop for a minute until he sees just what C. is going to do.

Article 5.

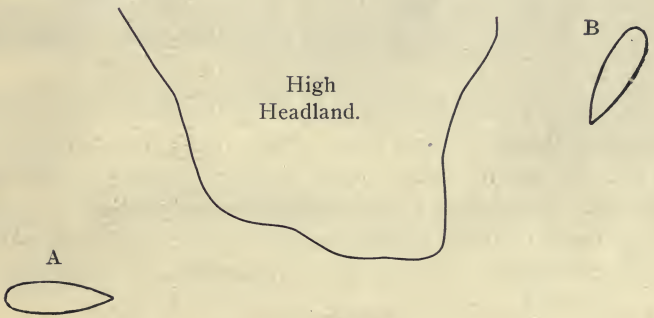


It is plain that the burden of this situation rests upon A. and C. B. has a tow and a fair tide and can't do anything in the way of stopping. A. certainly has the right of way over C., but as C. is about to head into the channel A. is coming out of, when the two vessels will come about head and head, it is proper for A. to at once blow 1 whistle and port, thereby giving C. a chance to round the buoy without crowding on B.; A. will then be in a good position to enter his channel. True A. might say "I have the right of way and shall maintain course and speed," this would be in accord with Art. 21 of the Pilot Rules; but consider the special circumstances, A. is nearly out of a narrow channel that B. and C. are about to enter; B. can't stop for the fair tide will sweep his barges round and obstruct the channel; C. could stop, but in the position they are about to get into, A. and C. will be in the head and head situation when they are supposed to blow 1 whistle and pass on the port side of each other, according to Rule I of the Pilot Rules; quickly taking all these things into consideration, A. remembers Art. 27 of the Pilot Rules, decides not to be a "road hog"

and acts as above stated. Art. 27 is here given in full with a recommendation for its use.

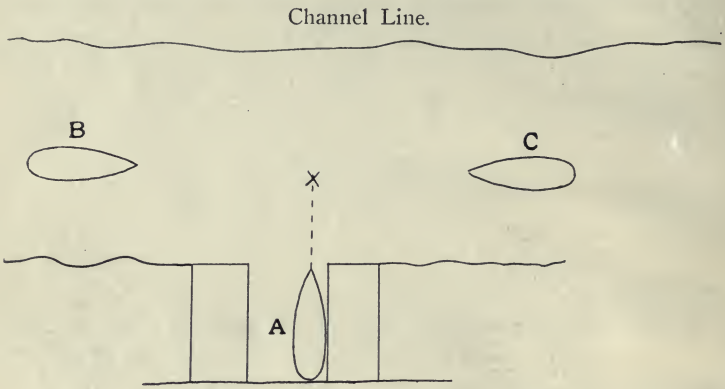
"In obeying and construing these rules, due regard shall be had to all dangers of navigation and collision, and to any special circumstances which may render a departure from the above rules necessary in order to avoid immediate dangers."

Article 6.



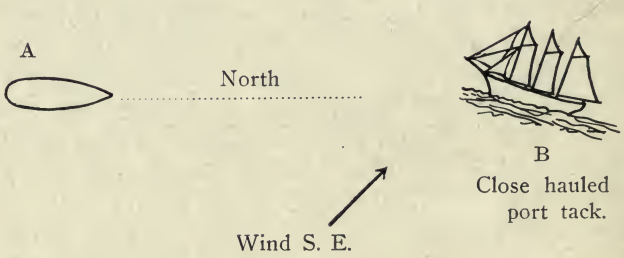
A. and B. are hidden from each other by the high land; Rule V directs that in this situation either vessel having arrived within half a mile of the turn shall blow 1 long blast which shall be answered by a similar blast by any approaching vessel within hearing. Suppose A. has arrived within the half mile limit, he blows 1 long blast which B. answers with a similar blast; then the passing signals are given by either and answered. In deciding which passing signal to give, the tide conditions and nature of the channel are taken into consideration. This is the only situation in which the law authorizes the use of the passing signals when the vessels are not in sight of each other.

This rule and signal apply to the case in which a steamer may be leaving her dock and other vessels may be approaching from any direction, but when she is clear of her berth and fully in sight, the steering and sailing rules apply.



A. blows 1 long whistle in leaving the dock; when fully in sight of B. and C. and clear of her berth, or about at the X, then the sailing rules apply, and the proper signals are exchanged according to the direction A. intends to take. A. ought not to leave until channel is clear, but if she does, B. and C. should stop until A.'s direction is determined.

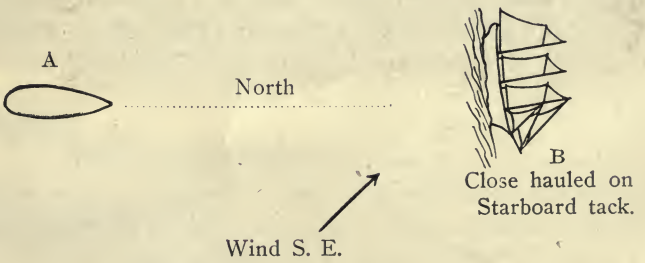
Article 7. **Fog Situations.**



Dense fog; so of course we assume that A. cannot see B.; but A. suddenly hears 2 blasts of a fog horn right ahead;

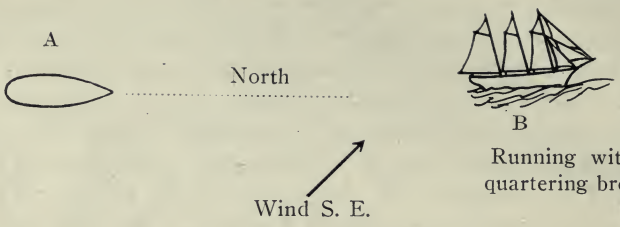
he knows first that a sailing vessel is ahead of him, distance off unknown; he knows second that she is on the port tack and may be heading anywhere from close hauled to a point where the wind is abeam, for with the wind abaft the beam, he would blow 3 blasts. Reasoning that a yacht close hauled might head up to within four points of the wind, while a square rigger would need six, he establishes at once the first point on which she may be heading as S. or four points from S. E. Then counting eight points from S. E., he fixes S. W. as the other possibility; because heading S. W. the wind, if S. E., would be abeam which establishes the limits of heading while blowing a 2 blast signal, viz. between S. and S. W. Having arrived at this conclusion almost the instant he hears the two blasts, for this whole process of reasoning is gone through with instinctively and instantaneously, A. ports a point or two until safely passed.

Article 8.



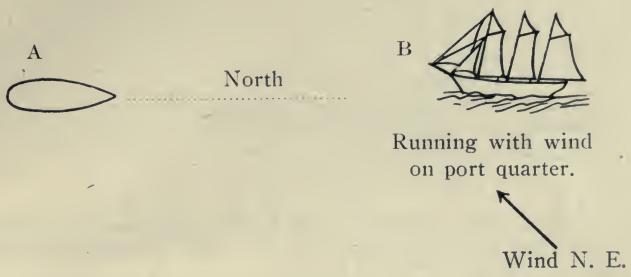
In this situation B. blows 1 blast and passing through the same reasoning as before, A. finds that she may be close hauled on starboard tack, perhaps heading up as high as East; or that she may have the wind abeam in which case she would be steering N. E.; therefore she may be between E. and N. E. so A. starboards a point or two, or until he brings the sound of the horn well on his starboard bow.

Article 9.



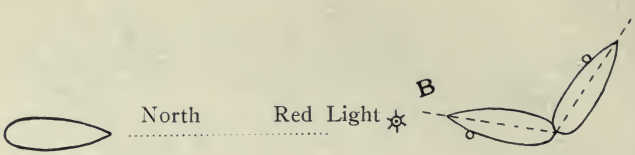
This is a more doubtful position than the others, for while the headings in Articles 7 and 8 can be determined within four points, this one can be anywhere in sixteen points. B. blows 3 blasts but A. at first is in doubt and stops until by subsequent signals he can determine nearly the heading. The reasoning is like this: At N. E. ¼ N., B. would begin blowing 3 blasts and should continue that same signal on any heading between there and S. W. ¼ W.; so if B. is heading at any sharp angle with A.'s course, A. will soon detect it, for the succeeding blasts of B.'s horn will sound more and more on the bow; but if the sound seems to remain about ahead, A. will figure that B.'s course is nearly on a line with his own and will start ahead again, either starboarding or porting a little as he thinks best; keeping a sharp lookout and listening for the echo of his whistle on B.'s sails. Always proceed with caution in this situation until sure of B.'s course. Sometimes it is a little help on the coast to judge of the probable course of B. by the coast line; if there are no harbors in the vicinity, or special turning points, it is fair to assume that B. is following a course somewhat in line with A, but this cannot be an infallible rule.

Article 10.



Here is the worst fix A. can get into with a sailing vessel, especially if there is any wind. B. is heading towards A., only A. can't determine that heading within sixteen points; it may be anywhere from N. W. ¼ W. to S. E. ¼ S. and he may not have time to take the bearing of B.'s horn, perhaps before a second signal is blown they may be together. Now what had A. better do? If he starboards his helm, it will prove all right if B. happens to be heading between S. and S. E.; but suppose he isn't? Suppose he is heading S. S. W.? A. has then made a fatal mistake, for he is hauling across B.'s bow, and it may prove the same if A. ports his helm. And so he cannot for a moment think to either starboard or port two or three points and then steady, but he should at once throw his helm hard over, one way or the other, he can't tell which will be the best unless his boat swings a little quicker on one helm than the other, and keep it there till he brings the next blast so far abaft his beam that the danger is over, when he gradually hauls back to his course. In a situation of this kind, don't hesitate an instant, but get the wheel over. Of course in a channel such a course need not be followed for the probable heading of B. could be established with a fair degree of accuracy, but out on the coast or ocean it is a very different affair. It is essential that the terms starboard and port tack are understood or the signals may be given wrong, or misinterpreted. The tack a vessel is on is named according to the side the wind is coming from, viz.: Starboard tack means that she has the wind on her starboard side. Many believe just the opposite, that it is named according to the side the booms are on; but this is an error and spells disaster if followed.

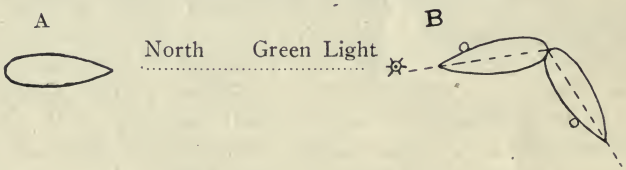
Article 11.



A. suddenly makes a red light about ahead and knows at once that he must port a little until he brings it out clear on his own port bow.

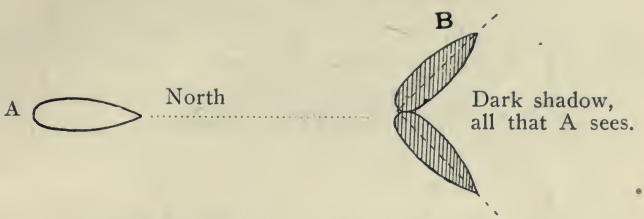
In the head and head situation A. would see both side lights, therefore he establishes S. (a little Westerly) as the first point of B.'s possible heading; and as a side light shows two points abaft a vessel's beam, it is at once evident that W. N. W. would be the last possible point that B. could be on, or count 10 points to the right of S. Therefore A. knows at once that B. must be heading between S. (a little Westerly) and W. N. W. and cannot be crossing his course; but as the angle between them may be very small, A. ports as described above in order not to crowd B.

Article 12.



In this situation it is the green light that A. makes ahead, so of course he starboards a little until it is out clear on his own starboard bow. The line of reasoning to be followed is the same as in Art. 11, whereby the two possible limits of heading of B. are established as S. (a little Easterly) and E. N. E. when his light would shut in altogether; or count ten points to the left of S.

Article 13.



Here A. sees the shadow of B.'s hull or sails without being able to at once determine his heading.

As at W. N. W. the red light became invisible, Art. 11, and at E. N. E. the green light disappeared, Art. 12, it is obvious that the dark angle is from W. N. W. through N. to E. N. E., or sixteen points. Quite a long range of possible headings and unless the actual one, or near it, is immediately determined, A. should throw his helm hard over, one way or the other, to be determined by which side there is the most room and by which helm his boat handles the more quickly on, and keep it there till B. is far enough on his bow as to render a collision impossible; then steady and haul back gradually to his course. If there isn't room to do this, stop and back at once until B.'s heading can be more accurately determined.

In either Art. 11, 12 or 13, if the light or shadow is made out on either bow, hastily determine the bearing and reverse it for one of the limits of heading and count the ten or sixteen points as the case may be to determine the other limit. For example, suppose in Art. 11, B. bore three points on A.'s starboard bow or N. E. x N., the opposite point is S. W. x S. when both side lights would appear, therefore S. W. x S. (a little Westerly) is one limit and ten points to the right or N. W. x N. is the other limit.

In that case, A. would have to act quickly and throw his helm hard a port to bring B. on his port bow.

CHAPTER EIGHT.

A Little Old Junk.

To Mark a Lead Line.

2	fathoms,	2 strips of leather
3	"	3 " "
5	"	white rag
7	"	red rag
10	"	leather with one hole
12	"	same as 2
13	"	blue rag, or same as 3
15	"	same as 5
17	"	" " 7
20	"	leather with 2 holes
25	"	1 knot
30	"	3 knots
35	"	1 knot
40	"	4 knots
45	"	1 knot
50	"	5 knots

Always mark the line wet and attach the lead to be used.

Arming — This is soap filled into a hole in bottom of lead to bring up a sample of the bottom.

To open a coil of new rope, laid and coiled right handed. Use the inside end and coil left handed in a large coil, leaving the bottom end in the center, when coiled once bring the bottom end up through the center and again coil left handed; bring the end up once more and coil right handed.

How to Construct a Drag — If for small boats or launches, lash together the oars, weight them, with the anchor, make fast your anchor rope and pay out, keeping the inboard end fast forward, the purpose being to keep her head to the sea if it is too heavy to run. If there are no oars, use anything at hand, such as gratings, deck chairs or settees.

Collision mat — This may be any piece of canvas drawn down over a hole below the water line. Make a rope fast to each corner of a square of canvas and haul it over the hole which may some times have a pillow, blanket or mattress stuffed into it first. Your boat may be saved from sinking by using a little ingenuity.

Use of Oil in Rough Water — If the sea is so rough as to be dangerous in running, take a potato sack, a canvas bag with holes punched in the bottom is better, put in a good sized wad of oakum or waste and saturate it with oil. Hang this over the side and the constant dripping of oil will form a slick near the boat so she can run with perfect safety. If hove to and shipping water it is just as valuable.

Points of the Compass — They are 32 in number, sub-divided into ½ and ¼ points.

N. ¼ E.	N. N. E. ¼ E.	N. E. ¼ E.	E. N. E. ¼ E.
N. ½ E.	N. N. E. ½ E.	N. E. ½ E.	E. N. E. ½ E.
N. ¾ E.	N. N. E. ¾ E.	N. E. ¾ E.	E. N. E. ¾ E.
N. x E.	N. E. x N.	N. E. x E.	E. x N.
N. x E. ¼ E.	N. E. ¾ N.	N. E. x E. ¼ E.	E. ¾ N.
N. x E. ½ E.	N. E. ½ N.	N. E. x E. ½ E.	E. ½ N.
N. x E. ¾ E.	N. E. ¼ N.	N. E. x E. ¾ E.	E. ¼ N.
N. N. E.	N. E.	E. N. E.	E.
E. ¼ S.	S. E. x E. ¾ E.	S. E. ¼ S.	S. x E. ¾ E.
E. ½ S.	S. E. x E. ½ E.	S. E. ½ S.	S. x E. ½ E.
E. ¾ S.	S. E. x E. ¼ E.	S. E. ¾ S.	S. x E. ¼ E.
E. x S.	S. E. x E.	S. E. x S.	S. x E.
E. S. E. ¾ E.	S. E. ¾ E.	S. S. E. ¾ E.	S. ¾ E.
E. S. E. ½ E.	S. E. ½ E.	S. S. E. ½ E.	S. ½ E.
E. S. E. ¼ E.	S. E. ¼ E.	S. S. E. ¼ E.	S. ¼ E.
E. S. E.	S. E.	S. S. E.	S.
S. ¼ W.	S. S. W. ¼ W.	S. W. ¼ W.	W. S. W. ¼ W.
S. ½ W.	S. S. W. ½ W.	S. W. ½ W.	W. S. W. ½ W.
S. ¾ W.	S. S. W. ¾ W.	S. W. ¾ W.	W. S. W. ¾ W.
S. x W.	S. W. x S.	S. W. x W.	W. x S.
S. x W. ¼ W.	S. W. ¾ S.	S. W. x W. ¼ W.	W. ¾ S.
S. x W. ½ W.	S. W. ½ S.	S. W. x W. ½ W.	W. ½ S.
S. x W. ¾ W.	S. W. ¼ S.	S. W. x W. ¾ W.	W. ¼ S.
S. S. W.	S. W.	W. S. W.	W.
W. ¼ N.	N. W. x W. ¾ W.	N. W. ¼ N.	N. x W. ¾ W.
W. ½ N.	N. W x W. ½ W.	N. W. ½ N.	N. x W. ½ W.
W. ¾ N.	N. W. x W. ¼ W.	N. W. ¾ N.	N. x W. ¼ W.
W. x N.	N. W. x W.	N. W. x N.	N. x W.
W. N. W. ¾ W.	N. W. ¾ W.	N. N. W. ¾ W.	N. ¾ W.
W. N. W. ½ W.	N. W. ½ W.	N. N. W. ½ W.	N. ½ W.
W. N. W. ¼ W.	N. W. ¼ W.	N. N. W. ¼ W.	N. ¼ W.
W. N. W.	N. W.	N. N. W.	N.

To box the compass is to learn the 32 whole points beginning N. x E., and then to say them backwards.

Placing the Compass — If there is no standing binnacle, have cleats fastened to the deck in the handiest place for the one steering, so that the compass is always in line with the keel, although it need not necessarily be amidships. Also select a place as far as possible from any magnetic metal especially if it is movable. If any fog running is to be done, this is most important.

To Anchor — Pick out your spot and bring her head to it; notice how the other boats are tailing. Stop early and let her way take her up, then if the tide doesn't sufficiently check her, give her a kick back and when she gathers stern board let go, and stop her. In letting go under head way, she will run up over the anchor and when she straightens back, the cable may come foul perhaps tripping the anchor; therefore this should be avoided as much as possible.

To Run Out a Kedge Anchor — Haul your boat up to where the anchor is being lowered and see that it has a long lashing in the ring, long enough to more than reach round your boat; and if you wish to trice it up for shoal water, have another on the crown; lower the anchor into the water and pass one part of the lashing under the boat; bring the two parts together and tie them, allowing the anchor to hang down amidships. Coil as much of the hawser into your boat as you can conveniently and run out in the desired direction, pulling the hawser first off the ship's deck; when that is all out, pay overboard from your coil until the end when the anchor lashing is cut. If you have a boat under oars, instead of a motor, make the ring lashing fast to the stern. If the water is shoal, haul up on the crown lashing, making it fast around the boat and up over the gunwales, which will carry the anchor more in line with the keel instead of perpendicular to it, and also distributes the weight.

Bell Signals to the Engine Room — From a stop, 1 bell, slow ahead. Jingle, full speed. 1 bell to slow down, 1 more to stop. 2 bells to back, jingle, full speed astern; then 1

bell stops. From full speed ahead to full speed astern, 4 bells and a jingle.

Study a Coast — If entering a strange harbor or coming on to a piece of coast that is new to you, make a study of it beforehand, don't wait till you get there. Get a general idea of the outline of the land, whether high or low, look up the soundings giving special attention to any dangerous shoals or reefs, find in the lighthouse book the description of any lighthouses or lights with their fog signals, and keep the book at hand to refresh your memory when needed. If you have a "Coast Pilot," look up what is said about this particular place, with special reference to the tides, strength of current, etc. Have your chart and lead at hand and keep a good lookout.

Buoys — The general rule is in entering a harbor, red to starboard and black to port; black and red horizontal stripes mark an obstruction in a channel, go either side and give it a good berth. Black and white perpendicular stripes are on channel buoys, meaning mid channel,— pass close to them; anchor buoys are white and are generally placed according to local conditions, giving vessels a chance to anchor back of them, leaving the channel free. This description of the painting applies to any type of buoy, the spar, a long straight stick; nun, a cone; can, a cylinder; whistling, tall type nun surmounted by a whistle; bell, generally a cage with a bell at top; gas, similar to the whistling, only instead of the whistle at the top has a lantern. Where nun and can buoys are used, the nuns are usually red and the cans black. Passing through a sound or roadstead from the E. toward the W., the buoys will be found as in entering a harbor. Red buoys all have even numbers, black buoys, odd numbers.

To Mark a Chip Logline — This was the method in use formerly to ascertain the speed of the ship and the line was marked by this example in proportion:

3600s : 6086 ft. : : 28 : 47.33 ft.

Therefore with a line marked for a 28 second glass, a knot is 47 feet, 4 inches long. An amount of stray line was left next the chip which was weighted on one edge to stand upright in the water, marked by a piece of red bunting, and each length of 47 feet, 4 inches after that by a piece of fish line with one, two or three, etc., knots in it, according to its number from the "stray line." Each knot was subdivided into five equal parts and a small piece of white bunting turned into the line at every two-tenths division thus formed. The chip is thrown over and when the "Stray" goes over the rail, the officer cries "Turn" and whoever holds the glass turns it, allowing the sand to begin running; when it has all run through he cries "Stop" and the officer snubs the line at once, counting up the knots and tenths. If the vessel's speed was greater than 4 knots, the fourteen second glass was used instead of the 28, and the number of knots run out was doubled. The 28 and 14 second glasses were called respectively the long and short glasses. This practice of measuring a ship's rate of sailing is founded upon the principle that the length of each knot is the same part of a sea mile as twenty-eight seconds is of an hour; it was much in vogue a few years ago but with the advent of fast steamships and the patent log it is practically extinct.

Strength of Rope — The strength of a rope yarn of medium size is 100 lbs., but the twist given it in laying up diminishes its strength after certain limits so that it varies from 76 lbs., in a 12 in. rope to 104 lbs., in ½ inch rope.

A Practical Rule for Ascertaining the strength of rope. The square of half the circumference gives the breaking strain of the weakest plain laid rope in tons, and is therefore a safe rule.

To Ascertain the Weight of Rope —Three strand, plain laid, 25 thread yarn, tarred; multiply the square of the circumference by the length in fathoms, and divide by 4.24 for the weight in pounds.

A practical rule for determining the relative strength of chain and rope. Using the diameter of the chain and the circumference of the rope, consider the proportionate strength of chain and rope to be 10 to 1. Half inch chain may therefore replace 5 inch rope. The breaking strain of chain may be found by dividing the square of the diameter in eighths, by 2.4 for round link chain, and by 2.7 for chain cable.

To find the weight a rope will lift when rove as a tackle. Multiply the weight the rope will sustain by the number of parts at the movable block, and subtract ¼ of product for resistance.

To find the size of rope when rove as a tackle to lift a given weight. Divide the weight to be raised by the number of parts at the movable block to get the strain on a single part; add ⅓ of this for the increased strain due to friction, and reeve the rope of the corresponding strength.

To find what number of parts of a **small rope** are equal to a large rope. Divide the square of the circumference of the larger rope by the square of the circumference of the smaller, and the result will be the number of parts of the smaller equal to one part of the larger.

Strength of Cotton Canvas — Cotton canvas is 22 inches wide and contains 80 running yards to the bolt. In No.'s 1, 2 and 3, the blue thread must be 1½ inches from the selvage; in No.'s 4, 5 and 6, 1¼ inches; in No.'s 7 and 8, 1 inch; in No.'s 9 and 10, ¾ of an inch. In testing, three strips crosswise and three strips lengthwise are cut; the strips to be each 1 inch wide and 22 inches

long except in No.'s 8, 9 and 10, which will be cut 1½ inches wide and 22 inches long.

Number of Canvas.	Pounds Weight Per Bolt.	Pound Weight Borne by Strips Crosswise.	Lengthwise
1	90	280	250
2	85	260	230
3	80	240	210
4	75	230	200
5	70	220	190
6	65	210	180
7	60	200	170
8	55	220	190
9	50	210	180
10	45	200	170

Helm — The term Starboard and Port refer to the helm, or tiller and not the wheel. With the wheel ropes rove straight and tiller forward of the rudder, throwing the wheel to port pulls the tiller to starboard and the boat's head goes to port; therefore starboarding the helm in that case means putting the wheel to port and vessel's head to port. Now suppose the wheel ropes are rove crossed, to pull the tiller to starboard, the wheel must be rolled to starboard and the boat's head goes to port as before. Hence the order to Starboard means that the boat's head shall be directed to port; and the order to Port that she shall be directed to starboard. In taking charge of a strange vessel, one of the first things to determine is the effect on the vessel's bow of turning the wheel in eiher direction. All outside ships have their wheel ropes rove straight so that the order to Starboard means throw the wheel to port; the vessel's head goes same as the wheel. In many inland boats the practice is just the reverse.

The statements relative to rope, chain, etc., taken from "Luce's Seamanship."

A FEW DON'TS.

Don't depend too much on what someone else does; he may be wrong.

Don't play the road hog.

Don't cross the other fellow's bow just to show off; your motor might stick and a collision result.

Don't place your compass near any magnetic metal.

Don't blow about never having had an accident; it is liable to be a boomerang.

Don't fail to answer signals.

Don't use cross signals.

Don't be ashamed to use caution; slow or stop in time.

Don't run full speed in a fog.

Don't present your broadside if you see a collision is inevitable; in the time you have, swing towards him and you are not as liable to be sunk; this is in case there is no chance to wiggle round him.

Don't be dead sure to the point of recklessness; the safe navigator believes it possible to make a mistake.

Don't forget to take your running lights with you, even though you intend to return before sunset; your plans may get a kink in them.

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